AIR QUALITY IN ONTARIO

Ontario

A review of the State of Air Quality by the Ministry of Environment and Energy

1992

ACKNOWLEDGEMENT

This report has been prepared by the staff of the Ontario Ministry of Environment and Energy, Air Quality and Meteorology Section of the Air Resources Branch with contributions by the staff of the Regional offices, Laboratory Services Branch and the Atmospheric Research and Special Programs Section of the Air Resources Branch.

Air quality data from Environment Canada's National Air Pollutant Surveillance Program (NAPS) monitoring sites in Ontario are also included.

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Contents

Figures

Executive Summary

This is the twenty-second annual report documenting air quality in Ontario. The report presents a summary of the 1992 air monitoring network, monitoring methods, air contaminant trend analyses and meteorological analyses in order to delineate the state of air quality in Ontario. New additions to this year's report include a section discussing selected toxic pollutants, an analysis of vehicle related impacts on air quality levels in downtown Toronto and a case study of lead levels in the vicinity of a secondary lead plant in downtown Toronto.

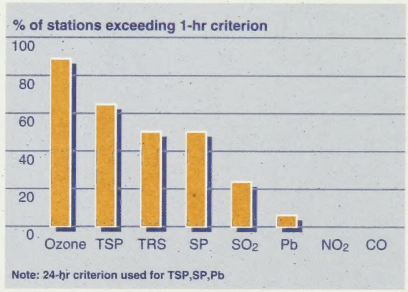
The Ontario routine air monitoring network was established in the early 1960s and reached its maximum size of 450 instruments in 1980. Since then, the number of monitoring instruments has been reduced by 15 percent such that in 1992 there were a total of 381 instruments: 262 continuous monitors and 119 Hi-vol particulate samplers.

Undesirable air quality (when the measured ground level concentration of a pollutant exceeds the ambient air quality criteria), as defined in Regulation 337 of the Environmental Protection Act was measured on a number of occasions during 1992. For continuously monitored contaminants, ozone, suspended particles, and total reduced sulphur compounds were the contaminants which exceeded the provincial ambient air quality criteria most frequently. The 1-hour ozone criterion was exceeded for at least one hour at 42 out of 48 ozone stations (87%); 17 out of 34 total reduced sulphur stations (50%) reported exceedances of the 1-hour total reduced sulphur pulp mill criterion; and the 24-hour criterion for suspended particles was exceeded at 21 out of 42 locations (50%) during 1992. Exceedances of the 1-hour criterion for sulphur dioxide were recorded at 15 out of 67 monitoring locations (22%).

Undesirable air quality levels were also reached on a number of occasions for the 24-hour averaged total suspended particulate concentrations. Out of 119 Hi-vol particulate stations, 75 (63%) recorded at least one exceedance of the 24-hour total suspended particulate criterion during the year. Two sites (located near lead processing plants) recorded exceedances of the 24-hour lead criterion during 1992.

The 22-year trends in air quality show significant decreases in average levels of lead (99%), sulphur dioxide (83%), carbon monoxide (79%), and total suspended particulates (61%). Nitrogen dioxide and oxides of nitrogen have decreased by 22% and 46% respectively over the past 18-year period while ozone has shown year to year variability over the last 14-years. For the corresponding emission levels in Ontario, the trend in sulphur dioxide emissions shows a 73% decrease over the 22-year period while over the past decade carbon monoxide and oxides of nitrogen emissions show decreases of 30% and 10% respectively.

Undesirable Air Quality in 1992
Based on Exceedance of Ontario AAQC



Average province-wide reductions of the ambient concentrations of sulphur dioxide, particulates, lead, carbon monoxide and oxides of nitrogen within the last two decades can be attributed to abatement activities associated with various air pollution regulations and policies which have been promulgated in Ontario during this period. Noteworthy regulations are Ambient Air Quality Criteria (Reg. 337), Air Pollution - General (Reg. 346) and the Lambton Industry Meteorological Alert (Reg. 350), all of which fall under the Environmental Protection Act.

Changing economic conditions have also forced a move towards more efficient and cleaner technologies in many areas. The oil crisis of the early 1970s, for example, led to smaller and more efficient vehicle engines with a resulting decrease in emissions per vehicle kilometer driven. Penalties for licensing bigger cars also had an impact on reducing vehicle emissions. Economic downturns also usually bring a temporary decline in pollution levels, simply because the economy is producing less and consuming less. Economic competitiveness in a global market introduces more modern and efficient technology resulting in reduced emissions.

There is little trend observed in the ground level ozone concentrations. In the northeastern U.S. and Canada, including southern Ontario, ozone episodes are a regional phenomenon. In 1992 there were 12 ozone episode days, which is significantly less than the 31 and 36 days recorded in 1991 and 1988 (a high ozone year) respectively but is comparable to the number of episode days recorded in 1990. However, the 751 exceedances of the Ontario 1-hour criterion of 80 parts per billion was less than the 917 recorded in 1990 and was approximately 17% of that recorded in 1988. Below average summertime temperatures in 1992 were responsible for the small number of exceedances. The meteorological variability together with the strong influence of the sources in the industrialised midwest U.S. are the primary reasons for the lack of trends in the ground level ozone concentrations.

Several initiatives, such as the Federal-Provincial NO_x-VOC Management Plan, the Federal-Provincial Air Quality Advisory and the Reid Vapour Pressure regulation are expected to reduce the contribution of Ontario's oxides of nitrogen and hydrocarbon sources to Ontario's ozone levels. However, control actions by the U.S. government would be required before any major reduction in the ozone levels in Ontario would be realized.

The Air Pollution Index, derived from a combination of sulphur dioxide and suspended particles, is the basis of the alert system for air pollution control in Ontario. The advisory level of 32 was reached on three occasions during 1992. A maximum air pollution index of 35 dominated by suspended particles was recorded at the Hamilton Downtown site on October 8.

Results from the Air Quality Index system show that during 1992, moderate to poor air quality was recorded for at least 1 hour at all air quality index sites. The frequency of days on which at least 1-hour of moderate air quality was recorded ranged from less than 1% to 54% depending on the site. Elevated levels of ozone and suspended particles were the most frequent cause of high index readings at the majority of air quality index sites across Ontario.

The Lambton Industrial Meteorological Alert, an early warning system established to prevent exceedances of the Ontario 24-hour criterion for sulphur dioxide of 100 parts per billion, was issued on 3 occasions in 1992. The longest duration of the alert was 17 hours, lasting from 1200 EST on May 6 to 0400 EST on May 7. The application of this alert is limited to a section of Lambton county (including Sarnia) in southwestern Ontario.

Ambient air quality levels for the criteria contaminants (sulphur dioxide, carbon monoxide, nitrogen dioxide, total suspended particulate and ozone) were compared for selected North American and International cities for the most recent comparable year, 1991. Canadian cities in the comparison were Toronto, Montreal and Vancouver. This comparison gives the state of Toronto's air quality relative to other cities in industrialised areas of the world. The relative position of Toronto's air quality depends on the pollutant considered and can vary from year to year due to variability in meteorology. For comparison, the pollutant levels for a number of cities are presented in an order ranging from the lowest to the highest values. For sulphur dioxide and total suspended particulate, Toronto's levels for 1991 were at the lower end of this order whereas for carbon monoxide and nitrogen dioxide they were at the higher end. Toronto's 1991 ozone levels were in the middle of the group of cities.

A southern versus northern Ontario air quality comparison indicated that combustion sources, including automobiles, power plants and other industries in high density urban areas, account for the higher levels of nitrogen dioxide and carbon monoxide in southern Ontario. Also, the significant long range transport contribution to ozone concentrations results in southern Ontario having higher hourly average concentrations due to the close proximity to the industrialised midwest U.S. Air quality in selected problem areas within Ontario is discussed in three case studies, i.e.; sulphur dioxide in Sudbury, vehicle impact on air quality levels in downtown Toronto, and lead levels in the vicinity of a secondary lead plant in downtown Toronto.

Meteorological conditions such as wind speed and direction, atmospheric stability, slow moving or stalled high pressure weather systems, and air temperature play a major role in the occurrence of elevated concentrations of various contaminants. Variations in pollutant concentrations from day to day are mostly due to meteorological factors.

It was found that during ozone episode events for the period 1988-1992, the 8-hour running mean of ozone concentrations in the ambient air reached the Occupational Health and Safety threshold limit value of 100 parts per billion on several occasions, primarily at rural sites. Generally, higher ozone levels at rural sites are due to less scavenging of ozone in rural areas and an increase in the production of ozone downwind of urban centres.

In addition to the common air pollutants, several organic compounds are also found in the ambient air as a result of industrial activities and vehicular emissions. Since these measurements have only been started in the last 2-3 years, a trend analysis of the data is not yet possible. Present measurements show the ambient concentrations of most of these organic compounds to be well below the Ontario standards where available. Efforts are underway through pollution prevention and other abatement programs to reduce their emissions.

Introduction

Ambient Air Monitoring

Ambient air monitoring in Ontario provides information on the actual concentration of selected pollutants in various communities. This information is used for the following purposes:

- ✓ Assessing the quality of the air in Ontario and evaluate trends;
- ✓ Informing the public on a real-time basis so they can respond appropriately to pollutant levels;
- ✓ Providing an episode warning and control mechanism for the protection of human health;
- ✓ Assessing the effectiveness of pollution reduction and abatement activities;
- ✓ Providing the basis for the development of air management strategies;
- ✓ Determining the progress in meeting Ontario's air quality criteria;
- ✓ Identifying areas of non-attainment;
- ✓ Quantifying the amount of pollution reduction required to meet the criteria;
- ✓ Providing quantitative measurements for abatement action on specific sources;
- ✓ Enabling the setting of meaningful air quality criteria;
- ✓ Assisting in the assessment of damage to vegetation and structures caused by air pollution;
- ✓ Supporting research activities on the effects of pollutants on health, property and vegetation.

The initial network established by the Air Pollution Control Division of the Ministry of Health in the early 1960s consisted of 20 hi-volume (Hi-vol) samplers for the measurement of suspended particulate matter and several lead peroxide and lime candles for the measurement of sulphur dioxide and fluorides.

In 1965, a meteorological program was developed in order to document atmospheric conditions. The initial program consisted of two 300 ft (91m) meteorological towers equipped at three levels to provide wind speed, wind direction and temperature.

In 1966 the sampling network was expanded to include automatic sampling for gaseous contaminants such as sulphur dioxide, oxides of nitrogen, total oxidants, carbon monoxide and total hydrocarbons.

With the passage of the Air Pollution Control Act in 1967, the task of air pollution control was centralized in an agency of the provincial government and by 1971 a total of 76 sampling sites (260 instruments) were operating across the province. In 1992, the provincial monitoring network consisted of 381 instruments: 262 continuous monitors at 99 sites and 119 Hi-vol particulate samplers. Meteorological monitoring was carried out at 34 locations in 1992.

This report describes the 1992 Ontario routine air quality monitoring program and includes a summary of the measurements of gases and particulate matter as well as a summary of meteorological conditions during the year. It is intended to be used in conjunction with the Appendix which appears in a separate volume. The characteristics, effects, Ontario criteria (if any), sources, method of monitoring, locations and frequency of sampling are discussed for each of the gaseous and particulate contaminants.

Additions to this year's report include a section discussing selected air toxics, an analysis of vehicle- related impacts on air quality levels in Toronto and a case study on lead levels in the vicinity of a secondary lead plant in downtown Toronto.

The ambient air quality data collected from the Ontario Ministry of the Environment and Energy monitoring network have been subjected to stringent quality control and quality assurance programs. The purpose of these programs is to ensure that the air quality data collected by the Ministry have attained acceptable levels of accuracy, precision and completeness.

SECTION A of this report gives a brief discussion of the quality assurance and quality control procedures as well as a description of the data base.

The entire continuous (hourly) network is summarized in the Appendix Table A-1 and Maps 1 and 2. This table gives station name, number, and an indication of the "continuous" pollutants measured. Letter codes indicate whether data were telemetered or chart-read.

The "continuous" measured contaminants include SP (suspended particles) measured in coefficient of haze (COH) units as well as the following gases:

SO_2	(sulphur dioxide)
CO	(carbon monoxide)
O_3	(ozone)
NO_2	(nitrogen dioxide)
NO	(nitric oxide)
NO_x	(oxides of nitrogen)
THC	(total hydrocarbons)
RHC	(reactive hydrocarbons)
TRS	(total reduced sulphur)

SECTION B of this report describes each of the "continuous" contaminants in sequence.

SECTION C deals with the Air Quality Index system, a recent five-year history of the Air Pollution Index and a brief summary of the Lambton Industrial Meteorological Alert system.

The (daily) particulate (Hi-vol) network is summarized in Appendix Table A-2 and Maps 4 and 5. This table provides station name, number, and the various "daily" pollutants measured. Also, numerals indicate the monitoring cycle frequency in days. Some additional codes are defined in the key at the top of the table. The main particulate contaminants measured are:

TSP	(total suspended particulate)
IP	(inhalable particulate)
Cd in TSP	(cadmium)
Cr in TSP	(chromium)
Fe in TSP	(iron)
Mn in TSP	(manganese)
Ni in TSP	(nickel)
Pb in TSP	(lead)
V in TSP	(vanadium)
Cu in TSP	(copper)
NO_3^- in TSP	(nitrate)
SO_4^{2-} in TSP	(sulphate)

SECTION D describes each of the "daily" or particulate contaminants under the headings of TSP, IP, Lead, Trace Metals, Nitrate and Sulphate. These data are typically collected at a frequency of once every 1, 3 or 6 days.

The (monthly) dustfall and fluoridation networks are summarized in Appendix Table A-3. This table provides station name, number and the various "monthly" parameters measured. The main "monthly" contaminants measured are:

TDF	(total dustfall)
FLR	(fluoridation rate)

SECTION E describes each of the "monthly" contaminants under the headings TDF and FLR. These data are collected at a frequency of once every month.

SECTION F of this report describes selected air toxics which include volatile organic compounds (VOC) and dioxins and furans. The selected toxics presented are benzene, formaldehyde, benzo(a)pyrene, methylene chloride (dichloromethane) and tetrachloroethene (perchloroethylene). Results for dioxins and furans are presented as an overall average.

SECTION G of this report depicts the provincial trends in air quality and emissions, a comparison of air quality levels in selected cities around the world for 1991, a brief analysis of the impact of vehicle- related emissions on air quality in Toronto, a discussion of the lead problem in the vicinity of a secondary lead plant in Toronto and a comparison of air quality levels in northern Ontario versus southern Ontario.

The meteorological network is described in Appendix Table A-5 and Maps 6 and 7. The table provides station name, numerical identifier, the various meteorological parameters measured as well as the height above ground at which the measurements were taken.

SECTION H summarizes the general meteorological conditions for 1992 and presents a discussion of ozone levels in Ontario.

SECTION I provides a reference list.

Glossary

COH

— the coefficient of haze measurement yields an estimate of the amount of fine suspended particulate matter by measuring the amount of light transmission.

Criterion

— a desirable maximum ambient air concentration or level (based on potential effects).

Detection limit

— the minimum concentration of a compound contaminant that can be determined by a specified analytical method.

Geometric mean

— a statistic of a data set calculated by taking the nth root of the product of all(n) values in a data set.

— provides a better indication than arithmetic mean of the central tendency for a small data set with extreme values.

Percentile value

— the percentage of the data set that lies below the stated value.

— for example, if the 70 percentile value is 0.10 ppm, then 70% of the data are equal to or below 0.10 ppm.

Primary pollutant

— a contaminant which is directly emitted to the atmosphere.

Secondary pollutant

— a contaminant which is formed from other pollutants present in the atmosphere.

Correlation coefficient

— a measure of the strength of the relationship between two variables.

"Continuous" pollutant

— a contaminant for which a continuous record exists; effectively, pollutants which have hourly data (maximum 8760 values per year).

"Daily" pollutant

— a contaminant for which there exists only a 24-hour or daily value (maximum 365 values per year).

"Monthly" pollutant

— a contaminant for which there exists only a monthly (30-day) value (maximum 12 values per year).

"Toxic" pollutant

— substance that can cause cancer, genetic mutations, organ damage, changes to the nervous system, or even physiological harm as a result of prolonged exposure, even to relatively small amounts.

Ozone "episode day"

— a day on which widespread (hundreds of kilometres) elevated ozone levels (greater than 80 ppb maximum hourly concentration) occur simultaneously at more than eight monitoring sites.

Abbreviations

AAQC
— ambient air quality criterion.

COH
— coefficient of haze reported as SP

ppb
— parts (of contaminant) per billion (parts of air).

ppm
— parts (of contaminant) per million (parts of air).

$\mu g/m^3$
— micrograms (of contaminant) per cubic metre (of air).

$gm/m^2/30$ days
— grams (of contaminant) deposited per square metre per 30-day period.

$\mu g/100\ cm^2/month$
— micrograms (of contaminant) per 100 square centimetres per month.

pq/m^3
— a millionth of a microgram (of contaminant) per cubibic metre (of air)

NAAQC
— National Ambient Air Quality Criterion.

USEPA
— United States Environmental Protection Agency.

TLV
— threshold limit value

UV
— ultraviolet radiation

SECTION A
Monitoring Network Operations

1.0 Network Description

In 1971 the provincial monitoring network consisted of 254 instruments: 166 continuous analyzers at 76 monitoring sites and 88 sites with Hi-vol samplers. By 1980, the provincial network had reached its maximum size at 450 instruments of which 268 were continuous analyzers at 106 sites and 182 Hi-vol monitors. Since 1980, the total number of instruments operating across Ontario has decreased by about 15%. In 1992, the network consisted of 381 instruments: 262 continuous monitors distributed at 99 sites to monitor up to nine different gaseous contaminants, and Hi-vol samplers at 119 sites. *Figure 1* shows the distribution of the number of instruments operating in Ontario since 1971.

The Ministry of the Environment and Energy is divided into six Regions. Each Region has an Air Resources Unit which is responsible for the day-to-day operation and maintenance of the air monitoring analyzers. Through a computer telephone line system, the technicians remotely check the automatic "zero" and "span" values each day to determine the stability of the instruments. The span gases used for these daily checks are assigned concentration values by the Instrumentation and Quality Assurance Unit of the Air Resources Branch.

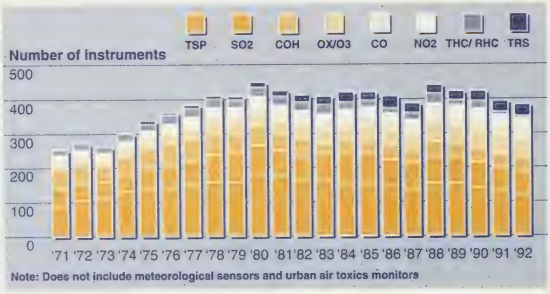
Regional technicians perform regular inspections and maintenance on the monitoring equipment and stations. If an instrument undergoes major servicing, the Instrumentation and Quality Assurance Unit may be requested to perform a calibration to confirm proper operation of the analyzer.

Portable calibration equipment is used by regional staff in evaluating instrument performances. This equipment is calibrated by the Instrumentation and Quality Assurance Unit a minimum of twice per year.

FIGURE 1

Ontario Ambient Air Quality Monitoring Program

(From 1971 to 1992)



Note: Does not include meteorological sensors and urban air toxics monitors

1.1 Quality Assurance and Quality Control

The Air Resources Branch maintains a laboratory with gas reference standards that adhere to those of the U.S. National Institute of Standards and Technology (NIST) as well as to the Pollution Measurement Division of Environment Canada. Performance audits are conducted on the SO_2, NO/NO_2, O_3 and TRS (as H_2S) monitors three times per year and on CO and hydrocarbon (as methane) monitors once per year. Hi-vol and PM-10 samplers are audited annually to determine the accuracy of the flow rate measurements. Deviation of ± 10 percent from the audit standard is the criterion for performance acceptability.

The ambient air quality monitoring network is subjected to continuous maintenance and quality control programs.

The real-time continuous and particulate air quality data are constantly reviewed, assessed and validated by Regional staff and staff of the Air Resources Branch. Remedial actions are taken immediately to rectify any problems that may affect the validity of the data.

In 1992, the provincial continuous air monitoring instruments were subjected to 733 performance audits. 82.5% of the audits were found to be within the acceptable

performance criterion of ± 10%. For the remaining 17.5% which fell outside the 10% criterion, station log records and backup charts were consulted to correct the data. As a result, the MOEE monitoring network for 1992 had 95.1% valid data *(See Figure 2a)*.

The Hi-vol samplers were subjected to 195 performance audits in 1992. 88% percent of the audited instruments were within the ± 10% acceptable criterion. *(See Figure 2b)*.

1.2 Data Base

The ambient air quality data used in this report are stored in MOEE's Air Quality Information System (AQUIS). Approximately 4 million air pollution measurements are added to AQUIS on an annual basis with the vast majority representing the more heavily populated urban areas within Ontario.

A statistical test, the pattern test is used as a data screening procedure to identify data anomalies. The pattern test checks for unusual pollutant behaviour. A set of limits for each pollutant has been defined from historical data. Values that are outside these limits are flagged for further investigation.

The AQUIS data are divided into three major groupings: continuous (1-hour) measurements, daily (24-hour) measurements, and monthly (30-day) measurements.

The hourly data are obtained from ambient air monitoring instruments that operate continuously, producing a measurement every hour for a possible total of 8760 hourly measurements in a year. A valid annual mean requires at least 5840 hourly readings or 67% valid data.

The daily measurements are obtained from instruments that provide one measurement from a 24-hour sampling period and are typically operated on every 1,3 or 6 days. Such instruments are used to measure total suspended particulates, inhalable particulate, lead, various trace metals, sulphate and nitrate. For daily data, a valid annual mean requires at least two thirds of the total number of possible samples, i.e., a station operating on a 6-day sampling schedule would require at least 40 out of a possible 61 samples.

The monthly data are collected over a 30-day period producing 12 monthly measurements per year. A valid annual mean requires at least seven out of a possible 12 values.

In order for a monitoring site to have been included in the 10-year trend analysis, the site had to have a valid annual mean for at least 8 out of the 10 years 1983-1992, and to be included in the "long term" trend analysis the site had to have a valid mean for at least 18 out of the 22-years 1971-1992.

FIGURE 2(a)

Continuous Monitors' Audit Results, 1992

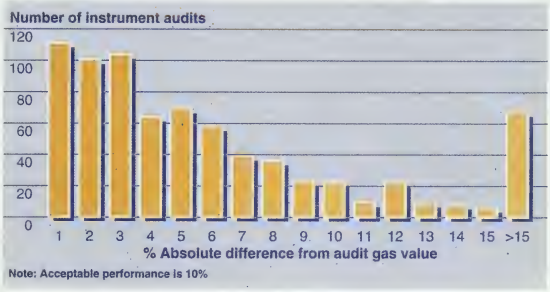
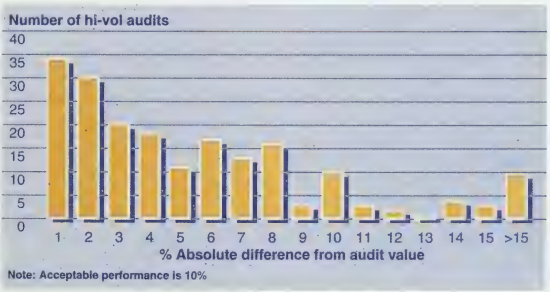


FIGURE 2(b)

Hi-Vol Flow Audit Results, 1992



SECTION B

Pollutants measured by continuous monitors (hourly data)

SO_2
SULPHUR DIOXIDE

2.1 Characteristics

SO_2 is a colourless gas with a strong, pungent odour at concentrations over 0.5 ppm. Sulphur dioxide can be oxidized (either photochemically or in the presence of a catalyst) to sulphur trioxide (SO_3), which in the presence of water vapour is readily converted to sulphuric acid mist. Other basic oxides combine with SO_3 to form sulphuric aerosols. Sulphuric acid droplets and other sulphates are thought to account for about 5% to 20% percent of the total suspended particulate in urban air. These compounds can be transported over large distances and deposited to the ground as a major constituent of acid precipitation. Many of the health problems attributed to SO_2 may be the result of the oxidation of SO_2 to other compounds.

2.2 Effects

At levels exceeding the Ontario ambient air quality criteria (AAQC), SO_2 can adversely affect both human health and vegetation. Human health effects include breathing discomfort, respiratory illness, alterations in the lung's defenses and aggravation of existing respiratory and cardiovascular disease. Major subgroups of the population most sensitive to SO_2 include asthmatics and individuals with chronic lung disease or cardiovascular disease.

Recent work by the Urban Air Group at McMaster University in Hamilton has shown that there is evidence that the frequency of visits to general practitioners in Ontario is associated with the level of SO_2 in the air. For every 1 part per hundred million (pphm) increase in annual average SO_2 there is one extra visit to the general practitioner for every person in the province per year. Examination of disease prevalence for chronic obstructive pulmonary disease shows an approximate 25% increase in prevalence associated with an increase of 1 pphm in annual mean SO_2.

The effects of sulphur dioxide on vegetation are historically the best known of the phytotoxic gases. Depending upon the concentration of the gas, duration of the fumigation, plant species and predisposing factors, sensitive plant foliage can suffer acute or chronic injury from sulphur dioxide. Both native and cultivated plant species can be injured in the vicinity of point sources (i.e., smelters or fossil-fuelled generating stations) or from accidental releases.

2.3 Ontario Criteria

0.25 ppm	(1-hour)
0.10 ppm	(24-hours)
0.02 ppm	(1-year)

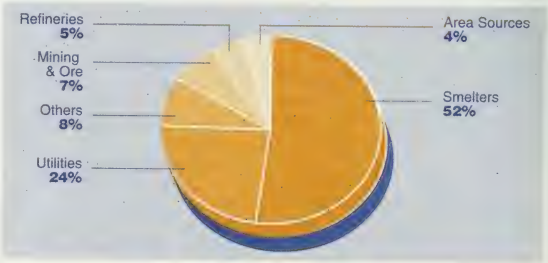
2.4 Sources

Approximately 75% of the SO_2 emitted in Ontario originates from non-ferrous smelters and electric utilities. A major fraction of the remaining 25% comes from other industrial sources including iron ore smelters, petroleum refineries, pulp and paper mills and area sources including residential, commercial and industrial space heating *(Figure 3)*. Reduction of SO_2 pollution levels can generally be achieved through the use of low sulphur content fuels or the use of chemical sulphur removal systems. Although

FIGURE 3

Ontario SO_2 Emissions by Sectors

(Man-Made Emissions, Late 1980s)



there are some natural sources of sulphur (i.e., volcanoes, swamps, etc.), these sulphur emissions in Ontario are very small compared to the emissions produced by our industrial society.

2.5 Method of Monitoring

The fluorescence of SO_2 excited by pulsed ultra-violet radiation is the method used.

2.6 Locations of Monitors

The Appendix provides a description of the provincial SO_2 network (Table A-1).

SO_2 monitoring was conducted at 67 locations in 1992.

2.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, and the maximum one-hour and 24-hour (midnight to midnight) values are provided in the Appendix (Table A-6). Also given are the number of exceedances of the sulphur dioxide criteria *(see Section 2.3)*.

The lowest annual average SO_2 level in the province was measured in Thunder Bay (63200), where the annual mean SO_2 level was close to 0.00 ppm.

The highest annual mean (0.011 ppm) was recorded at the Beach Boulevard site (29102) in Hamilton downwind of the city's industrial area. The greatest number of exceedances (64) of the 1-hour AAQC and the maximum 24-hour concentration (0.18 ppm) were both recorded at the Copper Cliff site (77218) in northeastern Ontario near the Inco Limited smelter operations.

Throughout the province there were a total of 15 SO_2 stations (13 in the Sudbury basin area) where the hourly SO_2 criterion was exceeded at least once but only one site (Copper Cliff) where the 24-hour criterion was exceeded. There were no exceedances of the annual criterion during 1992. *(See Table 1)*

SP
SUSPENDED PARTICLES

3.1 Characteristics

SP is defined as a relative measure of suspended particulate matter of size most likely to reach the lungs (diameter less than 5-10 microns). It is determined by the amount of light transmission due to the trapping of particles on a filter medium and is expressed as coefficient of haze (COH).

3.2 Effects

1 hour average

less than 2.0 COH units
— no known effects
2.0 COH units
— decrease in visibility
4.0 COH units
— soiling evident
6.0 COH units
— increasing sensitivity to indviduals with asthma and bronchitis

3.3 Ontario Criteria

1.0 COH unit (24-hours)
0.5 COH unit (1-year)

3.4 Sources

Industrial processes include combustion, incineration, construction, mining, metal smelting, processing and grinding. In the urban airshed, motor vehicle exhaust and road dust are the major sources of this material. The natural sources include wind-blown soil, forest fires, ocean spray, and volcanic activity.

3.5 Method of Monitoring

A continuous paper tape sampler with sampling inlet and flow rate regulated to favour small airborne particles is the method used. SP is determined by drawing a measured volume of air through a portion of paper tape. The tape is automatically advanced to produce a reading every hour. The reduction of light transmitted through the tape is expressed as coefficient of haze (COH) per 1,000 linear feet of air sampled.

3.6 Locations of Monitors

The Appendix provides a description of the provincial SP network (Table A-1).

Suspended particles were measured at 42 locations in 1992.

3.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, the maximum one-hour and 24-hour values, and the number of exceedances of the SP criteria (see Section 3.3) are provided in the Appendix (Table A-7).

The lowest annual levels measured in the province were at the Sudbury Science North monitor (77203) where the SP averaged 0.17 unit.

The greatest number of exceedances (17) of the 24-hour criterion and the highest annual mean (0.58 unit) occurred at the Mission site (31049), 381 Yonge Street, in an urban street canyon in Toronto. The highest measured value (4.8 units) was recorded at the College Street monitor (12016) in Windsor.

There was a total of 21 stations (50%) where the 24-hour criterion was exceeded at least once; the annual criterion was exceeded at only one station, the Mission site. *(See Table 1)*.

TABLE 1

Highlights of the Continuous Monitoring Network, 1992

	SO_2	SP	TRS	CO	THC	NO_2	NO	NO_x	O_3
Lowest Mean									
Location/Station	Thunder Bay (63200)	Sudbury (77203)	Tiverton (18007)	Sudbury (77203)	Mississauga (46117)	Long Point (22901)	Park Hill (15013)	Park Hill (15013) Long Point (22901)	Toronto (31103)
Concentration	0.00 ppm	0.17 Unit	0.1 ppb	0.1 ppm	1.34 ppm	0.006 ppm	0.001 ppm	0.008 ppm	12.5 ppm
Highest Mean									
Location/Station	Hamilton (29012)	Toronto (31049)	Terrace Bay (63093)	Toronto (31049)	Etobicoke (35033)	Toronto (31049)	Toronto (31049)	Toronto (31049)	Tiverton (18007)
Concentration	0.011 ppm	0.58 Unit	4.9 ppb	1.9 ppm	2.24 ppm	0.031 ppm	0.057 ppm	0.091 ppm	33.4 ppb
Most Criterion Exceedances - 1HR	64	N/A	404*	0	N/A	0	N/A	N/A	179
Location/Station	Copper Cliff (77218)		Terrace Bay (63093)						Long Point (22901)
Most Criterion Exceedances - 24HR	3	17	N/A	N/A	N/A	0	N/A	N/A	N/A
Location/Station	Copper Cliff (77218)	Toronto (31049)							
Number of Stations Exceeding 1HR AQC	15	N/A	17	0	N/A	0	N/A	N/A	42
Number of Stations Exceeding 24HR AQC	1	21	N/A	N/A	N/A	0	N/A	N/A	N/A
Highest Measured Value - 1HR	Sudbury	Windsor	Terrace Bay	Toronto	Mississauga	East York	N.York West	N.York West	CN Tower
Location/Station	(77096)	(12016)	(63093)	(31049)	(46117)	(32010)	(34020)	(34020)	(31190)
Concentration	0.81 ppm	4.8 Units	243 ppb	12.0 ppm	8.1 ppm	0.16 ppm	0.78 ppm	0.87 ppm	139 ppb
Total Number of Stations	67	42	34	29	6	36	36	36	48

*** Exceedances of pulp mill criterion of 27 ppb for 1-hour. Figures in brackets is station number Height of CN Tower monitor is 444 m.**

TRS

TOTAL REDUCED SULPHUR COMPOUNDS

4.1 Characteristics

The characteristics of TRS are offensive odours similar to rotten eggs or rotten cabbage.

4.2 Effects

1 hour average

less than 5 ppb
— no known effects

5 ppb
— odour threshold

27 ppb
— extremely odourous

1,000 ppb
— sensitive individuals may suffer nausea and headache due to severe odour

4.3 Ontario Criteria

Methyl Mercaptans
— 10 ppb (1-hour)

Hydrogen Sulphide
— 20 ppb (1-hour)

Total Reduced Sulphur (from Kraft Pulp Mills)
— 27 ppb (1-hour)

4.4 Sources

The industrial sources include the steel industry, pulp and paper mills, and refineries and the natural sources include swamps, bogs, and marshes.

4.5 Method of Monitoring

Reduced sulphur compounds are oxidized to SO_2 in a high temperature converter and the SO_2 concentration is measured using fluorescent excitation by ultra-violet radiation.

4.6 Locations of Monitors

The Appendix provides a description of the provincial TRS compounds network (Table A-1).

TRS monitoring was carried out at 34 locations in 1992.

4.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, and the one-hour and 24-hour maxima are provided in the Appendix (Table A-8).

The lowest average levels (0.1 ppb) measured in the province were at Tiverton (18007) on the western shore of Lake Huron. The highest annual mean (4.9 ppb), the greatest number of exceedances (404) of the 1-hour TRS pulp mill AAQC and the highest 1-hour value (243 ppb) were recorded at Terrace Bay (63093) in northwestern Ontario near a kraft pulp mill *(See Table 1)*.

Seventeen sites (50%) exceeded the 1-hour pulp mill criterion during 1992. Note that all sites are not in the vicinity of kraft pulp mills.

CO

CARBON MONOXIDE

5.1 Characteristics

Carbon monoxide is a colourless, odourless, tasteless and poisonous gas which is produced as a result of incomplete combustion of fossil fuels. It is of concern as an air pollutant because it has a strong affinity for haemoglobin and thus reduces the ability of blood to transport oxygen.

5.2 Effects

1 hour average

less than 30 ppm
— no known effects

30 ppm
— increased cardiovascular symptoms for smokers with heart disease

50 ppm
— increasing cardiovascular symptoms for non-smokers with heart disease.
Some visual impairment.

The health threat is most serious for those who suffer from cardiovascular disease. Healthy individuals are also affected but only at higher concentrations. Exposure to elevated levels is associated with impairment of visual perception, learning ability, manual dexterity and performance of complex tasks.

5.3 Ontario Criteria

30 ppm (1-hour)
13 ppm (8-hours)

5.4 Sources

The primary source of CO (about 75%) is from the transportation sector. A secondary source is fossil fuel combustion for residential space heating and commercial/industrial operations *(Figure 4)*.

5.5 Method of Monitoring

Non-dispersive infrared photometry based on the preferential absorption of infrared radiation by CO is the method used.

5.6 Locations of Monitors

The Appendix provides a description of the provincial CO network (Table A-1).

CO was monitored at 29 stations in 1992.

5.7 Monitoring Results

The distribution by percentile of the hourly data, the mean, and the maximum one-hour and eight-hour values are given in the Appendix (Table A-9).

The lowest annual average (0.1 ppm) was measured at Sudbury (77203) while the highest annual average (1.9 ppm) was recorded at the Mission site (31049) in Toronto. This monitor is located in the Yonge Street corridor exposing it to motor vehicle exhaust. The highest measured one-hour value (12 ppm) was recorded at both the Mission site and York (36030). The highest eight-hour value (8 ppm) was measured at Mission.

There were no exceedances of the Ontario one-hour criterion (30 ppm); or the eight-hour criterion (13 ppm) during 1992. *(See Table 1).*

THC/RHC
HYDROCARBONS

6.1 Characteristics

Total hydrocarbon compounds are primarily methane by weight (colourless, odourless) which is present at about 1.5 ppm in the ambient atmosphere. Non-methane hydrocarbons (or reactive hydrocarbons) are usually present at much lower levels. This fraction reacts with nitrogen oxides and other oxidants in the presence of sunlight to form ozone.

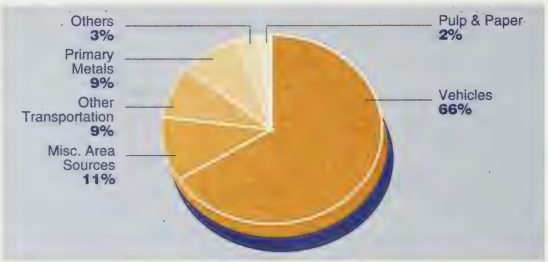
6.2 Effects

Effects depend on the individual chemical compound, which the analytical technique used in the measurement cannot identify.

6.3 Ontario Criteria

There is no Ontario AAQC for THC. However, criteria and standards exist for specific hydrocarbons and other organics.

FIGURE 4
Ontario CO Emissions by Sectors
(Man-Made Emissions, Late 1980s)



6.4 Sources

Anthropogenic sources include motor vehicles, gasoline storage tanks, petroleum and chemical industries, landfill sites, paint manufacturing, application and fermentation sites.

Natural sources include trees and other vegetation and decay of animal and plant materials.

6.5 Method of Monitoring

A calibrated flame ionization detector is used.

6.6 Locations of Monitors

The Appendix provides a description of the provincial THC/RHC network (Table A-1).

RHC was monitored at 1 location while THC was monitored at 6 locations in 1992.

6.7 Monitoring Results

The distribution by percentile of the hourly data, the mean, and the maximum one-hour and 24-hour values are given in the Appendix (Tables A-10 and A-11).

The locations and values for the lowest, and highest means are given in *Table 1.* The highest one-hour maximum concentration of reactive hydrocarbon compounds (1.7 ppm) was measured in Hamilton (the only site (29000), where the measurement is made in Ontario), while the highest 1-hour THC value (8.1 ppm) for the year was measured in Mississauga (46117).

NO_2
NITROGEN DIOXIDE

7.1 Characteristics

Nitrogen gas (N_2) is an abundant and inert gas which makes up almost 80% of the earth's atmosphere. In this form, it is harmless to mankind and essential to plant metabolism. Due to its abundance in the air, it is a frequent component in many combustion processes. When combustion temperatures are extremely high, as in the burning of coal, oil, gas and in automobile engines, atmospheric nitrogen (N_2) may combine with O_2 to form the various oxides of nitrogen (NO_x). Of these, nitric oxide (NO) and nitrogen dioxide (NO_2) are the most important contributors to air pollution.

NO_2 is a reddish-brown gas with a pungent and irritating odour over 0.10 ppm. It is an oxidation product of nitric oxide (NO) which is the primary NO_x emission. NO_2 reacts with hydrocarbons in sunlight to form ozone, and may be further oxidized to form nitric acid, a component of acid rain.

7.2 Effects

1 hour average

less than 0.10 ppm
— no known effects although may contribute to ozone and acid rain production.

0.10 ppm
— odour threshold

0.25 ppm
— some increase in bronchial reactivity in asthmatics

0.52 ppm
— increasing sensitivity to individuals with asthma and bronchitis.

Clinical studies reveal that odours are perceived at levels between 0.10 and 0.20 ppm for a few minutes. Epidemiological studies have indicated that children are susceptible to changes in pulmonary function which is induced by chronic exposure to NO_2 concentrations of 0.10 ppm.

NO_2 also has an effect on materials (i.e., corrosion of metals, fading of fabric dyes, degradation of rubber, etc.) and an adverse effect on vegetation.

7.3 Ontario Criteria

0.20 ppm	(1-hour)
0.10 ppm	(24-hours)

7.4 Sources

Anthropogenic sources are high temperature combustion processes including automobiles, power plants, incinerators and several chemical processes. In Ontario, the transportation sector accounts for about 60% of total NO_x emissions. *(See Figure 5).*

The natural sources of NO_x include lightning and soil bacteria. These natural emissions of NO_x are small compared to the anthropogenic emissions.

7.5 Method of Monitoring

Monitoring for oxides of nitrogen compounds is based on the principle of chemiluminescence involving a gas phase reaction of NO with ozone. For NO_2, the sample stream is passed through a catalytic converter where NO_2 is reduced to NO.

7.6 Locations of Monitors

The Appendix provides a description of the provincial NO_2 network (Table A-1).

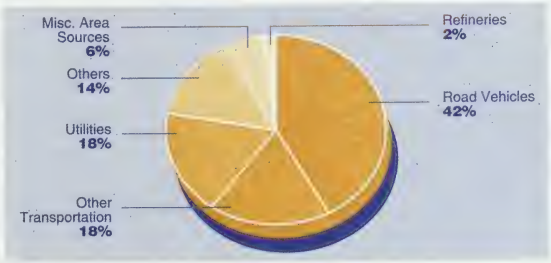
NO_2 monitoring was carried out at 36 locations in 1992.

7.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, and the maximum one-hour and 24-hour values is provided in the Appendix (Tables A-12). Also given is the number of exceedances of the NO_2 AAQC *(see Section 7.3).*

The lowest level (0.006 ppm annual mean) measured in the province was recorded at Long Point (22901) in westcentral Ontario. The highest annual mean (0.031 ppm) was measured in Toronto at the Mission site (31049), while the maxi-

FIGURE 5
Ontario NO_x Emissions by Sectors
(Man-Made Emissions, Late 1980s)



mum 1-hour value (0.16 ppm) was recorded at York (36030).

There were no exceedances of the 1-hour AAQC (0.20 ppm); or the 24-hour AAQC (0.10 ppm) during 1992. *(See Table 1).*

NO
NITRIC OXIDE

8.1 Characteristics

NO is a colourless and odourless gas which oxidizes to NO_2 in the presence of hydrocarbons and sunlight.

8.2 Effects

There are no known direct effects on health or vegetation at ambient levels.

8.3 Ontario Criteria

None

8.4 Sources

Same as for NO_2

8.5 Method of Monitoring

Same as for NO_2

8.6 Locations of Monitoring

Same as for NO_2

8.7 Monitoring Results

Parkhill (15013), a rural location in southwestern Ontario, recorded the lowest annual mean (0.001 ppm) while the Mission site (31049) in Toronto recorded the highest (0.057 ppm).
(See Appendix Table A-13 for the data summaries).

NO_x
OXIDES OF NITROGEN

9.1 Definition

NO_x is assumed to be the sum of NO_2 and NO concentrations in the atmosphere.

9.2 Effects

NO_x contributes to haze and visibility reduction and is also known to cause deterioration and fading of certain fabrics and damage to vegetation. Depending on concentration and extent of exposure, plants may suffer leaf lesions and reduced crop yield. Sensitivity of plants to nitrogen oxides depends on a variety of factors including species, time of day, amount of light, stage of maturity and the presence or absence of other air pollutants such as SO_2 and ozone.

9.3 Ontario Criteria

None

9.4 Sources

Same as for NO_2

9.5 Method of Monitoring

Same as for NO_2

9.6 Locations of Monitoring

Same as for NO_2

9.7 Monitoring Results

Parkhill (15013) and Long Point, rural locations in southwestern and westcentral Ontario respectively, recorded the lowest annual means (0.008 ppm). The highest annual mean(0.091 ppm) was recorded at the Mission Site (31049) in downtown Toronto. (See Appendix Table A-14 for the data summaries).

O_3
OZONE

10.1 Characteristics

Ozone is a colourless gas and a major component of photochemical oxidant compounds formed as the result of chemical reactions between nitrogen oxides and reactive hydrocarbons in the presence of sunlight. Two characteristics of ozone and oxidant exposures should be cited: (1) ozone itself is a primary cause of many of the health effects reported in toxicological and experimental human studies and the evidence for attributing many health effects to this substance alone is compelling; and, (2) the complex mixture of atmospheric photochemical substances is known to produce health effects, some of which are attributable to pure ozone but may be caused by other photochemical substances and other contaminants in combination with ozone. However, the naturally occurring ozone in the stratosphere is beneficial to life by shielding the earth from harmful ultra-violet (U.V.) radiation given off by the sun but high concentrations of ozone at ground level are a major health and environmental concern.

10.2 Effects

Ozone is a pulmonary irritant that affects the respiratory mucus membranes, other lung tissues and respiratory functions. Clinical and epidemiological studies have demonstrated that ozone impairs the normal function of the lungs, causing alterations in respiration rates, the most characteristic being shallow, rapid breathing. Exposure to ozone results in clinical symptoms such as chest tightness, coughing and wheezing. Alterations in airway resistance can occur, especially to

those with respiratory diseases (asthma, bronchitis, emphysema). These effects may occur in sensitive individuals as well as in healthy persons exercising vigourously, at concentrations in excess of 120 ppb.

Injury to vegetation is one of the earliest signs of photochemical air pollution, and sensitive plants are useful biological indicators of this type of pollution. Visible signs of these injuries due to ozone are flecking and discolouration of the leaves. Annual yield losses for selected crops in Ontario have recently been estimated to range from 1% to 12% when the seasonal average concentration ranged from 40 to 50 ppb. In 1980 the value of crop damage in Ontario was estimated to be about $23 million. Ozone also accelerates the aging of many materials, resulting in cracking of rubber, dye fading and paint erosion. These effects are related to the dose (time of exposure and concentration of ozone) and can occur at very low concentrations with long duration exposures.

10.3 Ontario Criteria

80 ppb (1-hour)

10.4 Sources

Ozone is produced by photochemical reactions and is not directly emitted into the atmosphere in significant amounts. Since it is formed downwind of nitrogen oxide and hydrocarbon sources and is capable of travelling long distances through the atmosphere, ozone is a manifestation of the long range transport of air pollution and a component of smog. Its formation and transport are dependent on meteorological factors. Warm temperatures are critical and elevated concentrations generally occur from May to September between noon and early evening. Ozone can also be formed naturally in the atmosphere by electrical discharge and in the stratosphere by solar radiation. The former process is not capable of producing significant urban concentrations of this pollutant; however, there is some belief that the incursion of ozone from the stratosphere can contribute significantly to elevated ground level concentrations of ozone under certain meteorological conditions.

10.5 Method of Monitoring

Chemiluminescence emission spectroscopy and U.V. absorption photometry methods are used to monitor for ozone.

In the first method, an air sample reacts with ethylene to emit visible light (chemiluminescence) of intensity directly proportional to the ozone concentration. In the second method, ozone absorption of U.V. light changes the intensity of the U.V. light beam, which is attenuated in proportion to the concentration of ozone. Most sites in Ontario use the UV absorption photometry method.

10.6 Location of Monitors

The Appendix provides a description of the provincial O_3 network (Table A-1).

Ozone monitoring was carried out at 48 locations in 1992.

10.7 Monitoring Results

The distribution by percentile of the hourly data, the mean, and the maximum one-hour and 24-hour values are provided in the Appendix (Table A-15). Also given are the number of exceedances of the ozone AAQC *(see Section 10.3)*.

1992 was an atypical year for ozone due to cool, moist summertime conditions which were not conducive for the production of high ozone concentrations. The lowest levels measured in the province were at the Toronto downtown site (31103) where the annual mean was 12.5 ppb. Toronto does not always record the lowest annual mean ozone concentration. However, because of the scavenging of ozone by nitric oxide, large urban centres do record lower levels of ozone than surrounding rural locations.

The highest annual mean concentration (33.4 ppb) was measured at Tiverton (18007) on the eastern shore of Lake Huron. The highest 1-hour maximum value (133 ppb), the highest 24-hour maximum value (103 ppb) and the greatest number of 1-hour exceedances (179) were all measured at Long Point (22901), a rural location on the northern shore of Lake Erie.

The CN Tower site (31190), where the height of the monitor is 444 metres above the ground recorded an annual mean value (33.4 ppb), a 1-hour maximum value of (139 ppb) and 163 exceedances of the 1-hour AAQC.

Concentrations aloft are generally higher than those at ground level and during the night the concentrations are decoupled from the ground by the nocturnal inversion. *(See Table 1)*. See also Section 28.0 for a detailed discussion of ozone in Ontario.

SECTION C

The Ontario air quality indices and Lambton alert

(AQI)

AIR QUALITY INDEX

11.1 Characteristics

The Air Quality Index (AQI) is a real-time information system that provides the public with an indication of air quality at 34 sites in 27 major cities across Ontario. The system has been in operation since June 1988. The AQI is derived from calculations involving pollutant concentrations which have evidence of adverse effects on the environment. These pollutants are sulphur dioxide, ozone, nitrogen dioxide, total reduced sulphur compounds, carbon monoxide and suspended particles. In addition, the Air Pollution Index (API) (Section 12.0) is also included as an AQI sub-index along with the eight-hour average concentration of CO. It should be noted that not all parameters are measured at all AQI sites. The AQI is provided to the public eight times daily; and the reporting frequency is increased to hourly releases when the index reaches 32, the level at which air quality is described as moderate.

11.2 Effect

The AQI sub-index is calculated on a hourly basis for each pollutant. The sub-index increases as the air quality deteriorates. The index values, the corresponding categories and the health and environmental effects are given in *Table 2*. The highest sub-index at the given time becomes the AQI.

If the index value reaches 50 - 99, the air quality may have adverse effects on the most sensitive of the human or animal population, or may cause significant damage to vegetation, property, or aesthetic value. An AQI value of 100 or greater may cause adverse effects to the health of a large sector of the exposed population.

11.3 Operation of the System

In 1992, there were 34 AQI monitoring sites in Ontario. The larger cities have more than one AQI station (See Map 3 in Appendix). The cities are selected according to population and previous air quality history. The data from the 34 AQI stations are accessed on a real-time basis by the computer center at the Air Resources Branch. The computed indices are released to the public and the news media 8 times daily. In addition, AQI forecasts based on the meteorological conditions are issued four times daily. In the event that one of the AQI stations has an index greater than or equal to 32, the AQI information is released hourly until it drops below 32. When the AQI is 50 or greater, the Medical Officer(s) of Health for the affected region is informed.

11.4 Air Quality Index Levels (1992)

The frequency distribution of the hourly AQI, according to descriptive category, and according to the pollutant responsible for AQI ≥ 32, is shown for the thirty-four AQI monitoring locations across Ontario in *Table 3*. From this table, it is evident that at the majority of sites suspended particles and ozone were the most frequent cause of elevated index readings. Total reduced sulphur compounds were the most frequent cause of high indices in Cornwall (56051), Fort Frances (62030) and Thunder Bay (63200). Ground level ozone which causes the index to be in the moderate/poor categories during the summer months was not as large a problem during the summer of 1992 since the weather/meteorological conditions were not conducive to the production of high concentrations of ground level ozone. In fact, during 1992 the number of occasions that the AQI was issued in the moderate/poor categories due to ozone was only 50% of those issued for this pollutant during 1990, the year that previously recorded the least number of ozone exceedances since the inception of the AQI system in 1988. *Figure 6* shows the total number of AQI exceedances recorded at AQI sites from 1988-1992. The total number of AQI exceedances during

FIGURE 6

Number of Hours of Moderate / Poor Air Quality at AQI Sites in Ontario (1988 - 1992)

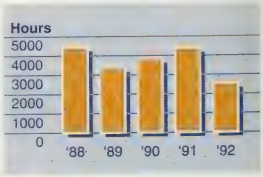


TABLE 2

Air Quality Index Pollutants and Their Impact

Index	Category	Carbon Monoxide CO	Nitrogen Dioxide NO_2	Ozone O_3	Sulphur Dioxide SO_2	Suspended Particles SP	SO_2 + SP (as measured by the API)	Total Reduced Sulphur TRS
100-over	Very Poor	Increasing cardiovascular symptoms in non smokers with heart disease, some visual impairment	Increasing reactivity of patients with asthma and bronchitis	Light exercise produces respiratory effects in patients with chronic pulmonary disease	Increasing sensitivity in patients with asthma and bronchitis	Increasing sensitivity in patients with asthma and bronchitis	Significant respiratory effects in patients with asthma and bronchitis	Sensitive individuals may suffer nausea and headaches due to severe odour
50 - 99	Poor	Increased cardiovascular symptoms in smokers with heart disease	Odour and discoloration. Some increase in bronchial reactivity in asthmatics.	Decreasing performance by athletes exercising heavily	Odourous, increasing vegetation damage	Visibility decreased, soiling evident	Increased symptoms in patients with chronic respiratory disease	Extremely odourous
32 - 49	Moderate	Blood chemistry changes but no detectable impairment	Odourous	Injurious to many vegetation species eg: white beans, tomatoes etc.	Injurious to some species of vegetation	Some decrease in visibility	Injurious to vegetation, to sulphur dioxide	Odourous
16 - 31	Good	No effects	Slight odour	Injurious to some vegetation species in combination with SO_2 (4 hrs.)	Injurious to some vegetation species in combination with ozone (4 hrs.)	No effects	No effects	Slight odour
0 - 15	Very Good	No effects	No effects	No effects	No effects	No effects	No effects	No effects

TABLE 3

Air Quality Index Summary, 1992

Stn ID	City Name	# of Hours AQI in Range					# of Hours Pollutant Responsible for AQI > 31						
		V.Good 0-15	Good 16-31	Mod. 32-49	Poor 50-99	V.Poor 100+	SO_2	SP	03	TRS	CO	API	NO2
44008	Burlington	7783	876	47	0	0	0	22	25	X	0	0	0
56051	Cornwall	7789	841	127	27	0	1	4	31	118	0	0	0
32010	East York	8027	632	31	0	0	0	31	0	X	0	0	0
35003	Etobicoke West	8042	718	24	0	0	0	14	10	X	0	0	0
35033	Etobicoke South	7706	1005	73	0	0	0	62	11	X	0	0	0
62030	Fort Frances *	7084	541	826	310	0	X	0	X	1136	X	X	X
28028	Guelph	8225	441	47	0	0	0	1	46	X	X	0	X
29000	Hamilton Downtown	7075	1598	111	0	0	0	54	7	11	0	39	0
29105	Hamilton East	8083	682	18	0	0	0	10	7	1	X	0	X
29114	Hamilton Mountain	7889	865	29	0	0	0	3	15	11	X	0	0
29118	Hamilton West	7106	1600	78	0	0	0	66	11	1	X	0	0
26060	Kitchener	8351	414	19	0	0	0	3	16	X	0	0	0
52020	Kingston+	3570	89	4	0	0	X	X	4	X	X	X	X
15001	London	8330	433	21	0	0	0	6	15	X	0	0	0
46110	Mississauga	8016	731	37	0	0	0	29	8	X	0	0	0
27056	Niagara Falls	8281	457	34	0	0	0	0	34	X	X	0	X
34020	North York Central	8158	606	20	0	0	0	4	16	X	0	0	0
34025	North York West	7065	1640	79	0	0	0	75	4	X	0	0	0
75010	North Bay	8246	450	28	0	0	0	5	23	X	0	0	0
44015	Oakville	7879	867	38	0	0	0	20	15	3	0	0	0
45025	Oshawa	8202	546	29	0	0	0	17	12	X	0	0	0
51001	Ottawa	8295	479	10	0	0	0	3	7	X	0	0	0
14064	Sarnia	8198	569	18	0	0	0	1	16	1	0	0	0
71068	Sault Ste Marie	8145	506	28	1	0	0	24	0	5	X	0	0
33003	Scarborough	8443	332	9	0	0	0	5	4	X	0	0	0
27067	St. Catharines	8305	444	35	0	0	0	11	24	X	0	0	0
77203	Sudbury	8328	410	28	1	0	8	1	20	0	0	0	0
63200	Thunder Bay	8596	157	17	0	0	0	3	0	14	0	0	0
31103	Toronto Downtown	7876	843	11	0	0	0	11	0	X	0	0	0
31120	Toronto West	8005	717	47	0	0	0	29	18	X	0	0	0
26045	Waterloo #	4710	103	1	0	0	0	0	1	X	X	0	X
12008	Windsor University	8094	640	50	0	0	0	26	24	X	0	0	0
12016	Windsor College	7502	1132	138	12	0	0	83	62	5	X	0	X
36030	York	7546	1143	87	0	0	0	65	22	X	0	0	0

Footnotes: * Fort Frances - TRS and SP only pollutants monitored.

+ Kingston - O_3 only pollutant monitored, Kingston reported less than 50% of the hours.

Waterloo - terminated during July 1992 X Pollutant not monitored at this site.

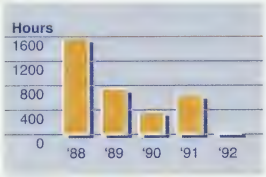
1992 was the least recorded at AQI sites since the inception of the system in 1988. This is due in part to the below average number of bright sunshine hours and the above average amount of precipitation during the summer of 1992. *Figure 7* shows the number of ozone exceedances recorded at AQI sites during the months of July, 1988 to 1992. This figure shows that the number of exceedances (19 hours) recorded during July 1992 was approximately 1.2% of those recorded during July 1988. Prior to 1992, the lowest number of ozone exceedances (359) at AQI sites, was recorded during July 1990. July is usually the single worst month for ozone exceedances. From 1988 to 1991, July ozone exceedances averaged 45% of the exceedances for the corresponding June, July and August period.

The total number of hours of moderate/poor air quality is shown in *Figure 8*; and *Figure 9* shows the number of days with moderate/poor air quality at AQI sites across Ontario. The number of hours/days

FIGURE 7

Number of Hours of Moderate / Poor Air Quality due to Ozone at AQI Sites in Ontario

(during the months of July, 1988 to 1992)



during which the air quality was in the moderate/poor range for at least one hour at each AQI site is shown in *Table 4*. From this table it should be noted that during 1992, Fort Frances (62030) recorded at least one hour of moderate/poor air quality on approximately 54 % of the monitoring days as compared to Cornwall (56051) at 19 %, Windsor College (12016) at 11 %, York (36030) at 12 % and Hamilton Downtown (29000) at 8 %.

(API)

AIR POLLUTION INDEX

12.1 Characteristics

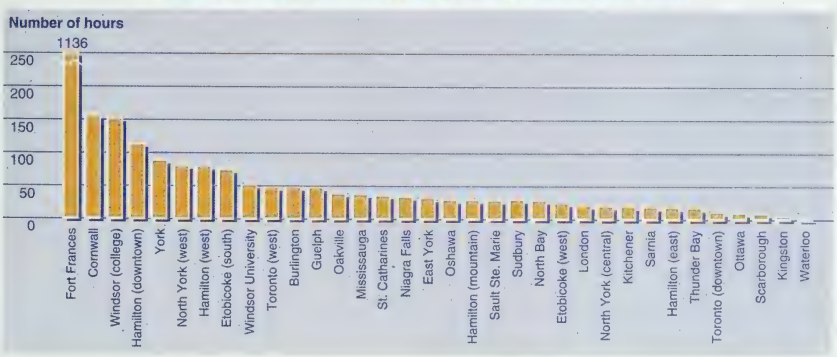
The API continues to be the basis of an alert and control system to warn of deteriorating air quality and is derived from 24-hour running averages of SO_2 and SP. Research studies have linked respiratory illness to elevated concentrations of SO_2 and particulates.

12.2 Legislation

Regulation 346 under the Ontario Environmental Protection Act (1971) authorizes the Minister of the Environment to order any point source not essential to public health or safety to curtail or cease its operations when air pollution levels occur which may be injurious to health.

FIGURE 8

Number of Hours of Moderate / Poor Air Quality at AQI Sites in Ontario



12.3 Operation of the System

The API is computed each hour based on the past 24 hourly values for SO_2 and SP. If the index reaches a value of 32 and if the Duty Meteorologist predicts a continuation of adverse atmospheric conditions for at least six hours, an Air Pollution Advisory is issued. Owners of significant sources of pollution are advised to prepare for possible curtailment of operations.

If the index reaches 50, and if at least six hours of adverse atmospheric conditions are forecast, owners of major sources may be ordered to curtail operations. This is the First Alert Level.

A Second Alert is issued at an API of 75, and further curtailment may be ordered.

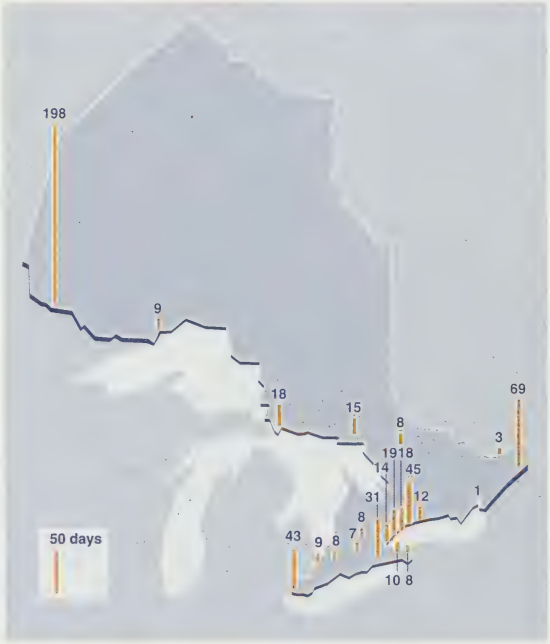
The Air Pollution Episode Threshold Level occurs at an API of 100. If atmospheric conditions are not expected to improve for at least six hours, owners of all sources not essential to public health or safety may be ordered to cease operations.

12.4 Air Pollution Index Levels

A history of the Air Pollution Index levels over the last 5 years of its operation is provided in *Table 5*. The table shows that only the Hamilton Downtown API site recorded levels in the advisory range during 1991 and 1992. *Figure 10* shows the API trends at Toronto Downtown and Hamilton Downtown for the period 1971 - 1992. The graph indicates that there has been a continuous decline in the number of episodes recorded at these sites. The maximum API values recorded at these two sites were 62 at Toronto Downtown during 1975 and 55 at Hamilton Downtown during 1979.

FIGURE 9

Number of Days with Moderate / Poor Air Quality in Ontario, 1992



13.0 Lambton Industrial Meteorological Alert (LIMA)

The Lambton Industrial Meteorological Alert System (LIMA) is part of the Environmental Protection Act - Reg. 350. The application of this alert is limited to that part of the county of Lambton bounded by Lake Huron, the St. Clair River, the King's Highway known as No. 80, the roadway known as Moore Township Road 31 and its continuation through that part of the King's Highway known as No. 40 and Lambton County road 27, which includes the City of Sarnia.

The Minister may declare an Alert when the 24-hour running average sulphur dioxide concentration at any station in the Lambton Industrial Meteorological Alert system reaches 0.07 ppm and meteorological forecasts indicate a continuation for six hours or more of weather conditions conducive to elevated SO_2 concentrations. The alert is issued at 0.07 ppm so as to prevent exceedance of the 24-hour SO_2 AAQC (0.10 ppm).

Two monitoring sites are located in Sarnia (Front Street and Centennial Park), one in Corunna (River Bend) and one in Michigan (Port Huron).

During 1992 the alert was issued on three occasions. The longest duration of the alert was 17 hours lasting from 1200 EST on May 6,

1992 to 0400 EST May 7, 1992. The maximum 24-hour running average SO_2 concentration during this episode reached 0.089 ppm and was recorded at the River Bend monitoring site. The 0.089 ppm recorded during this alert at River Bend was the highest 24-hour running average SO_2 recorded during 1992 at the monitors in the Lambton Industrial Meteorological Alert System.

Of the three alerts issued during 1992, two were for Front Street and one was for River Bend.

On one other occasion the LIMA reached 0.07 ppm but the alert was not issued since the meteorological conditions were not conducive for the build up of SO_2 concentrations.The number of LIMA alerts called over the past 10 years is displayed in *Table 6* below:

TABLE 6

Lambton Industrial Meteorological Alert Summary

(1983 - 1992)

Year	Alerts Called	Average Duration (Hours)
1983	5	18
1984	7	15
1985	3	16
1986	8	14
1987	0	N/A
1988	5	24
1989	3	12
1990	9	16
1991	8	23
1992	3	13

TABLE 4

Number of Hours/Days of Moderate/Poor Air Quality at AQI Sites, 1992

Station ID	City Name	Number of Hours AQI > 31	Number of Days at least 1 Hour - AQI > 31
44008	Burlington	47	14
56051	Cornwall	154	69
32010	East York	31	14
35003	Etobicoke West	24	11
35033	Etobicoke South	69	29
62030	Fort Frances *	1136	198
28028	Guelph	47	8
9000	Hamilton Downtown	111	31
29105	Hamilton East	19	11
29114	Hamilton Mountain	30	15
29118	Hamilton West	78	30
26060	Kitchener	19	7
52020	Kingston +	4	1
15001	London	21	8
46110	Mississauga	36	18
27056	Niagara Falls	41	8
34020	N. York Central	20	8
34025	N. York West	79	35
75010	North Bay	28	8
44015	Oakville	38	19
45025	Oshawa	29	12
51001	Ottawa	10	3
14064	Sarnia	18	9
71068	Sault Ste Marie	30	18
33003	Scarborough	9	5
27067	ST. Catherines	34	10
77203	Sudbury	29	15
63200	Thunder Bay	18	9
31103	Toronto Downtown	11	8
31120	Toronto West	47	23
26045	Waterloo ***	1	1
12008	Windsor University	49	17
12016	Windsor College	150	43
36030	York	88	45

* Fort Frances - TRS and COH only pollutants monitored.

\+ Kingston - O_3 only pollutant monitored, station malfunctioned during summer.

*** Station terminated during July 1992.

TABLE 5

Number of Occasions API > 31 at Sites Across Ontario

(1988 - 1992)

Stations	1988	1989	1990	1991	1992
Hamilton Downtown	1 (43)	3 (37)	2 (42)	1 (34)	3 (35)
Sudbury			2 (42)		
Windsor (12016)		1 (32)			
Toronto West		1 (33)			
East York		1 (34)			
Scarborough		1 (34)			
North York West		1 (38)	1 (32)		
Etobicoke West	1 (33)				
Etobicoke South		2 (33)			
York	2 (38)	1 (33)			
Burlington		1 (34)	2 (34)		
Mississauga		1 (35)			
London		1 (32)			
Hamilton Mountain		1 (38)			
Hamilton West			1 (32)		

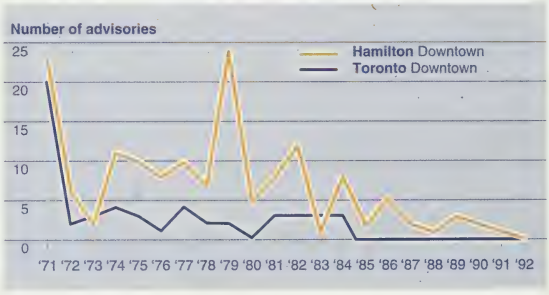
For stations: Toronto Downtown, Windsor(12008), Niagara Falls, Sarnia, St. Catharines, North York Central, Oakville, Oshawa, Kitchener, Waterloo, Guelph, Hamilton East, Sault Ste Marie, North Bay, Ottawa, Cornwall, ThunderBay, there were no recorded API advisories during 1988 - 1992

NOTE: Figure in brackets is maximum API value

FIGURE 10

Number of API Advisories Recorded at Toronto and Hamilton

(1971 - 1992)



SECTION D

Pollutants measured by high volume samplers (daily data)

TSP

TOTAL SUSPENDED PARTICULATES

14.1 Characteristics

Total suspended particulate is a generic term for airborne particles including smoke, fume, dust, fly ash and pollen. Composition varies with place and season but normally includes soil particulates, organic matter, sulphur and nitrogen compounds and metals such as lead. Size range is approximately 0.1 to 100 microns (diameter).

14.2 Health Effects

The greatest impact on health is from particles less than 10 microns in diameter which can penetrate deep into the lungs and contribute to respiratory disease (see Section 15.1). More serious health effects may be associated with suspended particulate matter which contains a toxic particulate component or which has absorbed a gaseous pollutant on the surface of the particles. Corrosion, soiling, damage to vegetation and visibility reduction are additional effects.

14.3 Ontario Criteria

120 $\mu g/m^3$
(24-hours)

60 $\mu g/m^3$
(1-year - geometric mean)

14.4 Sources

Particulate matter is emitted from industrial processes which include combustion, incineration, construction, mining, metal smelting, processing and grinding. In the urban airshed, motor vehicle exhaust and road dust are the major sources of this material *(Figure 11)*. Natural sources of particulate matter include wind-blown soil, forest fires, ocean spray and volcanic activity.

The provincial anthropogenic particulate emissions (excluding forest fires, road dust, etc.) are about 200 kilo-tonnes per year with fuel combustion being the largest single contributing sector. The natural sources such as forest fires and vehicle entrained road dust can be a much larger contributor than direct industrial or combustion emitters of particles.

14.5 Method of Monitoring

TSP is measured by an instrument called a Hi-vol sampler. Air is drawn through a filter at the rate of approximately 1.4 cubic metres per minute (m^3/min). The (daily) mass concentration of total suspended particulate matter is computed gravimetrically from the mass of collected particles and the volume of air sampled.

14.6 Location and Frequency of Monitoring

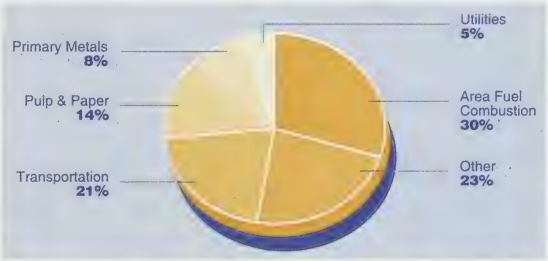
The monitoring locations and the frequency of sampling at each location are indicated in the Appendix (Table A-2).

TSP was measured at 119 locations in 1992.

FIGURE 11

Ontario Particulate Emissions by Sectors

(Man-Made Emissions, Late 1980s)



14.7 Monitoring Results

The distribution by percentile; the maximum and the geometric mean are given in the Appendix (Table A-16). Also given are the number of exceedances of the 24-hour and 1-year criteria. The lowest level measured in the province was at Dorset (49010) where the annual geometric mean was 10 $\mu g/m^3$.

The highest annual geometric mean (81 $\mu g/m^3$) was recorded at Hamilton (29011) in the heart of Hamilton's industrial centre. The maximum daily value (3200 $\mu g/m^3$) was measured in Toronto at station 31065 and was attributed to a process upset at a nearby industry. The greatest percentage of exceedances (22) of the 24-hour criterion occurred at the Stanley Avenue monitor (27055) in Niagara Falls near an abrasives manufacturing plant.

There were a total of 75 stations (63%) which exceeded the 24-hour criterion and 9 (13%) which exceeded the one-year criterion. *(See Table 7a).*

IP
INHALABLE PARTICULATE

15.1 Characteristics

The term "PM-10 fraction" has been given to the fraction of the total suspended particulate which has a diameter of 10 µm or less. This has been determined to be the particle size which is most likely to be inhaled and deposited into the thoracic region of the lung.

15.2 Effects

The major health effects associated with exposure to particulate are effects on pulmonary function, aggravation of existing pulmonary and cardiovascular disease, effects on mucocilliary clearance and mortality. Exposure to high levels of particulate in conjunction with exposure to sulphur oxides contributed to the high mortality rates following pollution episodes in New York and London, England in the 1950's. During particulate episodes, young children, the elderly, heart patients, asthmatics and those with influenza are the groups at risk. Corrosion, soiling, damage to vegetation and visibility reduction are additional effects of concern.

15.3 Ontario Criteria

Ontario presently does not have a standard for PM-10; however, a joint Federal/Provincial Air Quality Committee is in the process of developing a standard based on health effects.

15.4 Sources

Same as for TSP.

15.5 Method of Monitoring

IP is monitored by a modified Hi-vol sampler outfitted with a size selective inlet to restrict particle size to less than 10 µm. The daily mass of the inhalable particulate is computed from the mass of the collected particles and the volume of air sampled. Quartz fibre filters are used as the filter medium for collection. The ministry is currently evaluating a real time inhalable particulate monitor which, if proven successful, could provide IP measurements on a real time basis.

15.6 Location and Frequency of Monitoring

PM-10 monitoring locations are shown in the Appendix, Map 8. All sites operated on a one in 6-day sampling schedule. During 1992, inhalable particulate was measured at 23 locations.

15.7 Monitoring Results

The distribution by percentile, the maximum and the geometric mean are given in the Appendix, (Table A-17), for inhalable particulate as well as for sulphate and selected inhalable trace metals such as copper, iron and manganese. There are presently no criteria for these trace metals in the inhalable particulate size fraction.

For the inhalable particulate, the highest annual geometric mean (32 $\mu g/m^3$) was recorded at the Hamilton industrial area Gertrude/Depew monitor (29313) while the maximum daily value (170 $\mu g/m^3$) was recorded at the Bonney Street monitor (71342) in Sault Ste Marie *(See Table 7a).*

A comparison of inhalable particulate versus TSP was done for all available data collected during 1992. *Table 7b* summarizes the data as to the number of samples, the mean and maximum recorded values of IP and TSP, the percentage IP of the TSP loading, the linear equation expressing IP in terms of TSP and the corresponding r value. IP varies from 38% of the TSP loading at the Thorold site to 61% of the total loading at the Merrifield site in Sault Ste. Marie.

TABLE 7(a)

Highlights of the Particulate Hi-Vol Monitoring Network, 1992

	TSP	IP	Pb	Cr	Fe	Mn	Ni	Cu	NO_3^-	SO_4^{2-}	V
Lowest Geom Mean					London (15015) Corunna (14030)	Courtright (14016) Corunna (14030)		London (15015) Woodstock (17025)			
Location	Dorset (49010)	Thunder Bay (63201)	Several	Several			Several		Copper Cliff (77070)	Thunder Bay (63200)	Several
Concentration	10 µg/m³	17 µg/m³	0.00 µg/m³	0.005 µg/m³	0.007 µg/m³	0.005 µg/m³	0.005 µg/m³	0.00 µg/m³	0.00 µg/m³	4.4 µg/m³	0.005 µg/m³
Highest Geom Mean			Mississauga (46046)								
Location	Hamilton (29011)	Hamilton (29313)	Hamilton (29011)	Windsor (12038)	Hamilton (29011)	Hamilton (29011)	Copper Cliff (77070)	Copper Cliff (77070)	Windsor (12016)	Hamilton (29025)	Several
Concentration	81 µg/m³	32 µg/m³	0.24 µg/m³	0.028 µg/m³	3.8 µg/m³	0.265 µg/m³	0.128 µg/m³	0.21 µg/m³	4.7 µg/m³	11.4 µg/m³	0.008 µg/m³
Percentage of Samples Above 24-HR AQC											
Location	Niagara Falls (27055)		Mississauga (46041)								
Value	22	N/A	1	0	N/A	0	0	0	N/A	N/A	0
No. of Stations Exceeding 24-HR AQC	63	N/A	2	0	N/A	0	0	0	N/A	N/A	0
No. of Stations Exceeding 1-YR AQC	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Highest Measured Value-24-HR											
Location	Toronto (31065)	S.S. Marie (71342)	Mississauga (46041)	Thorold (27042)	S.S.Marie (71042)	S. S. Marie (71042)	Copper Cliff (77070)	Copper Cliff (77070)	Nanticoke (22904)	Toronto (31103)	Courtright (14016)
Concentration	3200 µg/m³	170 µg/m³	9.20 µg/m³	800 µg/m³	64.4 µg/m³	1.810 µg/m³	1.66 µg/m³	3.14 µg/m³	14.6 µg/m³	41.5 µg/m³	0.160 µg/m³
Total Number of Stations	119	23	66	42	48	44	44	46	29	29	42

(Figure in brackets is station number)

TABLE 7(b)

Comparison of Inhalable Particulate (IP) Versus Total Suspended Particulate (TSP), 1992

City	Station Location	N	Mean IP	Mean TSP	Max IP	Max TSP	% IP of TSP	IP = A + B (TSP)	r
Windsor	Wright/Water	46	22	45	54	138	49	IP = 4.0 + .40 (TSP)	.91
Windsor	3665 Wyandotte St. E.	49	25	59	66	135	42	IP = 5.4 + .34 (TSP)	.70
Windsor	467 University Ave.	54	20	41	60	144	49	IP = 5.8 + .37 (TSP)	.72
London	801 Commissioners	46	15	26	50	112	58	IP = 2.9 + .47 (TSP)	.83
Nanticoke	Walpole P. S.	26	15	24	60	82	60	IP = -.36 + .70 (TSP)	.75
Thorold	185 Queen St. S.	36	25	65	60	145	38	IP = 9.0 + .27 (TSP)	.62
Oakville	Bronte Rd/Woburn Cr.	51	19	38	60	84	50	IP = 2.4 + .45 (TSP)	.72
Hamilton	Buchanan P. S.	38	22	40	72	143	55	IP = 2.1 + .51 (TSP)	.94
Hamilton	Elgin/Kelley	54	26	60	80	209	43	IP = 6.4 + .34 (TSP)	.86
Hamilton	Beach Blvd.	46	22	53	71	117	42	IP = .98 + .41 (TSP)	.82
Hamilton	Gertrude/Depew	53	32	70	110	335	46	IP = 21.1 + .19 (TSP)	.53
Toronto	Bay/Grosvenor	64	21	43	74	148	49	IP = 3.3 + .41 (TSP)	.88
Etobicoke	Evans/Arnold	48	23	54	48	115	43	IP = 5.5 + .33 (TSP)	.81
Scarborough	Kennedy/Lawrence	53	21	47	69	139	45	IP = 5.7 + .35 (TSP)	.76
St. Catharines	71 King St.	50	21	40	58	111	53	IP = 3.7 + .44 (TSP)	.78
Thunder Bay	615 James St. S.	57	13	30	53	128	43	IP = 2.5 + .36 (TSP)	.91
S.S. Marie	Bonney St.	47	29	59	170	355	49	IP = 5.3 + .42 (TSP)	.95
S.S. Marie	Wm. Merrifield P. S.	53	17	28	52	96	61	IP = 4.5 + .45 (TSP)	.94
Fort Frances	250 Church St.	25	17	35	40	107	49	IP = 10.6 + .22 (TSP)	.65
Sudbury	19 Lisgar St.	53	15	32	47	90	47	IP = 2.1 + .43 (TSP)	.89

N = Number of data points r = Correlation coefficient IP is measured by PM-10 sampler Units are in µg/m³ Mean - Geometric mean

Pb

LEAD IN TOTAL SUSPENDED PARTICULATE

16.1 Characteristics

Lead is a silver-bluish, white, soft metal with a molecular weight of 207.20. It is a stable element which persists and accumulates both in the environment and in the human body. Lead enters the body primarily through ingestion and inhalation with subsequent absorption into the blood stream and distribution to all body tissues.

16.2 Effects

Clinical, epidemiological and toxicological studies have demonstrated exposure to lead adversely affects human health. Lead can degrade renal function, impair haemoglobin synthesis, and alter the nervous system.

16.3 Ontario Criteria

5.0 $\mu g/m^3$
(24-hours)

2.0 $\mu g/m^3$
(30-day - geometric mean)

16.4 Sources

Lead sources include combustion of gasoline containing lead additives, secondary smelting of lead, battery manufacturing, metal fabrication, some paint and glass manufacturing, production of iron, steel, copper and nickel. Lead emissions fell significantly after 1975 with the introduction of lead-free gasoline.

16.5 Method of Monitoring

The lead concentration on glass fibre filters is analyzed by either X-Ray fluorescence or atomic absorption.

16.6 Location and Frequency of Monitoring

The monitoring locations and sampling frequency for each location are indicated in the Appendix (Table A-2).
Lead was measured at 66 locations in 1992.

16.7 Monitoring Results

The distribution by percentile, the maximum, the arithmetic mean and the geometric mean are given in the Appendix (Table A-18). Also given is the number of exceedances of the 24-hour criterion.

The maximum 24-hour concentration (9.20 $\mu g/m^3$) and the highest annual geometric mean (0.24 $\mu g/m^3$) all occurred at the Dixie Road monitor (46046) in Mississauga. This monitoring site is located in the vicinity of a lead processing plant.

There were a total of 2 stations (located near lead processing plants) which exceeded the daily criterion at least once *(see Table 7a)*.
See *Section 26.0* for a analysis of lead levels in the vicinity of a secondary lead plant in Toronto.

Trace Metals in TSP

CADMIUM, CHROMIUM, IRON, MANGANESE, NICKEL, VANADIUM, COBALT, COPPER

17.1 Characteristics

Name	Symbol	Properties	Molecular Weight
Cadmium	Cd	silverwhite, hexagonal	112.41
Chromium	Cr	steel grey, cubic	52.00
Iron	Fe	silver, cubic	58.85
Manganese	Mn	grey-pink, cubic	54.94
Nickel	Ni	silver, cubic	58.60
Vanadium	V	light grey, cubic	50.94
Cobalt	Co	Silver, grey, cubic	58.93
Copper	Cu	Red, cubic	63.55

17.2 Effects

The depth of penetration into the respiratory system (and consequently risk to health) increases as particle size decreases. Of the heavy metals, cadmium, chromium, vanadium and manganese probably pose the greatest risk to human health. Soiling and damage to vegetation are additional effects.

17.3 Ontario Criteria

	24 Hour Criterion	Limiting Effects Based On
Cadmium	2 $\mu g/m^3$	Health
Chromium	1.5 $\mu g/m^3$	Health
Manganese	2.5 $\mu g/m^3$	Health
Nickel	2 $\mu g/m^3$	Vegetation
Vanadium	2 $\mu g/m^3$	Health
Copper	50 $\mu g/m^3$	Health
Iron	N/A	

17.4 Sources

See Section 14.4.

17.5 Method of Monitoring

The collection method is by Hi-vol Sampler (see Section 14.5). Following determination of TSP, a portion is cut from the exposed filter and ashed to destroy carbonaceous matter. The ashed sample is then digested in acid, and analyzed by atomic absorption spectrophotometry. The mass concentration of each metal in ambient air is calculated from the mass of each metal in TSP and the volume of air sampled, and expressed in $\mu g/m^3$.

17.6 Location and Frequency of Sampling

The monitoring locations and the sampling frequency for each location are indicated in the Appendix (Table A-2).

Metals were measured at 42 to 49 stations depending on the element.

17.7 Monitoring Results

The distribution by percentile of the daily data, the maximum, the arithmetic mean, the geometric mean, and the number of exceedances of the daily criterion are provided in the Appendix for cadmium, chromium, iron, manganese, nickel, vanadium, cobalt and copper (See Table A-19 through A-25). Table A-26 shows the maximum monitored levels for all the trace metals listed above. No table is provided for cobalt because a large percentage of the values were below the detection limit.

Table 7a provides the highlights of particulate monitoring for 1992. It shows that there were no exceedances of the air quality criteria for metals (exclusive of lead) during 1992.

NO_3^-
NITRATE

18.1 Characteristics

Nitrogen oxides are formed from atmospheric nitrogen and oxygen through high temperature combustion, photochemical reactions or bacterial action and may react with other compounds in the air to form nitrate (NO_3^-), nitric acid (HNO_3) or other nitrogen containing compounds.

18.2 Effects

Nitrate and nitric acid are involved in corrosion of materials, visibility degradation and acidic precipitation. They may also have an adverse effect on human health.

18.3 Ontario Criteria

None

18.4 Sources

Nitrate is primarily a secondary pollutant. Anthropogenic sources of nitrogen oxides or nitrates include all high temperature combustion processes, transportation, and fertilizer production and usage. Natural sources include lightning, biological decomposition and photochemical reactions.

18.5 Method of Monitoring

Nitrates are collected on glass fibre filters by a Hi-vol sampler and they are extracted by distilled water. This extract is reduced to nitrite followed by colourimetric analysis for determination of the mass concentration particulate phase nitrate.

18.6 Location and Frequency of Monitoring

The monitoring locations and the length of the sampling cycle (in days) for each location are indicated in the Appendix (Table A-2).

Nitrate monitoring was carried out at 29 locations in 1992.

18.7 Monitoring Results

The distribution by percentile, the maximum, the arithmetic mean, and the geometric mean are given in the Appendix (Table A-27). Highlights of monitoring are summarized in *Table 7a*.

The highest annual geometric mean nitrate concentration (4.7 µg/m^3) occurred in Windsor (12016) and the highest concentration for a single day (14.6 µg/m^3) occurred in Nanticoke (22904).

SO_4^{2-} SULPHATE

19.1 Characteristics

Sulphur dioxide is oxidized in the atmosphere to eventually form sulphate compounds. Intermediates in the oxidation process such as H_2SO_3 and SO_3 rapidly combine with water vapour to form sulphuric acid aerosol. This type of process is dependent on atmospheric conditions.

19.2 Effects

Sulphate compounds have been linked to respiratory irritation and disease, corrosion of materials, reduction of visibility and the formation of acidic precipitation.

19.3 Ontario Criteria

None.

19.4 Sources

Sulphate is primarily a secondary pollutant. Anthropogenic sources of sulphur oxides include the burning of fuels containing sulphur (such as coal and oil), the smelting of sulphur-containing ores and the refining of petroleum. Natural sources include bacterial decomposition, volcanoes and forest fires.

19.5 Method of Monitoring

Sulphate is collected on glass fibre filters by a Hi-vol sampler and it is extracted by distilled water. This extract is analyzed colourimetrically and the mass concentration of sulphate is calculated. It has been found that artifact sulphates form on the glass fibre filters from ambient SO_2 and that reported sulphate concentrations are therefore artificially high. No attempt has been made to correct the data reported here.

19.6 Location and Frequency of Monitoring

The monitoring locations and the length of the sampling cycle (in days) for each location are indicated in the Appendix (Table A-2). Sulphate monitoring was carried out at 29 locations in 1992.

19.7 Monitoring Results

The distribution by percentile, the maximum, the arithmetic mean, and the geometric mean are given in the Appendix (Table A-28). Highlights of monitoring are summarized in *Table 7a*.

The highest annual geometric mean sulphate concentration (11.4 µg/m^3) was measured at Hamilton (29025) and the highest concentration (41.5 µg/m^3) for a single day occurred in downtown Toronto (31103).

SECTION E

Pollutants measured by dustfall jar and fluoride candle (monthly data)

TDF

TOTAL DUSTFALL

20.1 Characteristics

Total Dustfall is a measure of the amount of settleable particulate in the atmosphere. The larger, more visible fraction of the particulate matter will settle out more rapidly than the fine particulate. Composition varies with place and season but normally includes soil particulates, organic matter, sulphur and nitrogen compounds, metals and re-entrained road dust.

20.2 Effects

There are generally no health effects associated with total dustfall; however, adverse health effects may be associated with dustfall which contains a toxic component or which has absorbed a gaseous pollutant on the surface of the particles. Corrosion, soiling, damage to vegetation and visibility reduction are additional effects.

20.3 Ontario Criteria

7.0 g/m^2/30 days
(30 days)

4.6 g/m^2/30 days
(1-year arithmetic mean)

20.4 Sources

Same as TSP and SP (COH).

20.5 Method of Monitoring

Dustfall is collected by exposing an open top plastic jar for 30-days. The total amount of dustfall is determined by weighing the contents of the jar and expressing the results in g/m^2/30 days.

The settleable particulate collected in the dustfall jar can be separated into a soluble and insoluble fraction for further analysis. The insoluble portion can be examined using an optical microscope to determine the composition of the particulate. Total dustfall can be analyzed for metals and other compounds which are listed in the Appendix (Table A-3).

20.6 Location and Frequency of Monitoring

Dustfall was measured at 168 locations throughout the province in 1992. The monitoring locations are indicated in the Appendix (Table A-3).

20.7 Monitoring Results

The monthly values, the maximum, the geometric standard deviation and the arithmetic and geometric means are given in the Appendix (Table A-29).

The highest annual arithmetic mean (12.2 g/m^2/30 days) was recorded at the station (29036) in the heart of Hamilton's industrial area. The highest monthly value (39.0 g/m^2/30 days) was recorded at the Fort York monitor (31183) in Toronto and was related to road construction activity.

There were a total of 85 stations (50%) which exceeded the monthly (30-day) criterion and 41 stations (24%) which exceeded the 1-year criterion.

FLR

FLUORIDATION RATE

21.1 Characteristics

Fluoridation rate is a measurement designed to indicate relative amounts of gaseous fluorides present over an extended period of time.

21.2 Effects

Fluorides cause damage to vegetation. A classic example is a reddish-brown discolouration at the margins of the leaf.

21.3 Ontario Criteria

40 µg/100 cm^2/30 days - growing season:

(April 1 - October 31 for southern Ontario);

(May 1 - September 30 for northern Ontario)

80 µg/100 cm^2/30 days -

(November 1 - March 31 for southern Ontario);

(October 1 - April 30 for northern Ontario)

21.4 Sources

Anthropogenic sources include fossil fuel power plants, brick manufacturing plants, fertilizer plants, petroleum refineries, aluminum smelters and the steel industry.

21.5 Method of Monitoring

A lime impregnated filter paper is exposed to ambient air for 30-days and subsequently analyzed for fluoride content.

21.6 Location and Frequency of Monitoring

Fluoridation rate was measured at 74 locations in 1992. The monitoring locations are indicated in the Appendix (Table A-3).

21.7 Monitoring Results

The monthly values, the maximum, the standard deviation and the arithmetic and geometric means are given in the Appendix (Table A-30).

The highest annual arithmetic mean (616 µg/100 cm^2/30 days) was recorded at Hamilton (29127) with the highest monthly value (2091 µg/100 cm^2/30 days) also measured here. This station is immediately adjacent to a brick manufacturer.

During the growing season, 39 stations (52%) recorded exceedances of the monthly 30-day criterion.

SECTION F

Airborne Toxic Chemicals

A range of airborne toxic chemicals is monitored in the province, in both urban and rural areas. These compounds include semi-volatile polynuclear aromatic hydrocarbons (PAH), dioxins and furans and a range of volatile organic compounds (VOC). The PAH and certain of the VOC, especially compounds like benzene, and toluene, are measured in urban and industrial areas because they are potentially harmful to human health. VOC can also contribute to photochemical production of ozone.

These monitoring activities began recently, and data are only available for one or two years. It will thus be some time before trends in the concentrations of these species are available. In this report recent data for these compounds are presented, and a comparison is made with corresponding measurements in rural, presumably clean, parts of Ontario. A comparison is also made with concentrations measured in other jurisdictions, where these data are available. *Figure 12* shows the location of the urban toxics sites (PAH, VOC and dioxins).

A large number of chemical compounds is monitored in each of the networks, in excess of thirty in each of the classes of PAH and VOC. To be included in the list a chemical must meet the following two criteria:

➤ It must be known to be toxic; or must be strongly suspected of being toxic to humans or to the ecosystem.

➤ It must be known to be, or suspected of being, present in the area where monitoring takes place.

This report focuses on a limited set of chemicals believed potentially most harmful to human health. The chemicals considered are:

Benzene	Methylene chloride (dichloromethane)
Formaldehyde	Tetrachloroethylene (perchloroethylene)
Benzo(a)pyrene	Dioxins and Furans

FIGURE 12

Location of Urban Toxic Monitoring Sites

Map Reference	Site Name	VOC	B (a)P	Dioxins / Furans
1	Windsor	*	*	*
2	London	*		
3	Hamilton	*		
4	Oakville	*		
5	Mississauga	*		
6	Toronto, North York	*	*	*
7	Stouffville	*		
8	Oshawa	*		
9	Cornwall	*		
10	Dorset	*	*	*
11	Sault Ste. Marie	*	*	
12	Thunder Bay	*	*	
13	Sarnia	*		
14	Walpole Island	*		
15	Ottawa	*		

AIRBORNE TOXIC CHEMICALS IN URBAN AREAS

22.1 Sources and Sinks

Although small amounts of certain of these chemicals are produced naturally, the sources are overwhelmingly associated with human activities. Benzene is present as a component of gasoline. It is thus emitted to the atmosphere in the course of the production, distribution and marketing of gasoline, and is also emitted by gasoline powered motor vehicles. Formaldehyde is used industrially, for example in the production of certain plastics. It is also used as a fungicide and preservative (formalin is an aqueous solution of formaldehyde). Formaldehyde is emitted in the exhausts of alcohol- fuelled vehicles, and is produced in the atmosphere in the course of the photochemical reactions which produce smog.

Also known as dichloromethane, methylene chloride is used as a degreasing solvent, in the preparation of metal components for further fabrication or painting. Tetrachloroethene (synonyms tetrachloroethylene or perchloroethylene) is a key chemical used in the dry cleaning process.

Benzo(a)pyrene is a PAH (polynuclear aromatic hydrocarbon). It is formed in small quantities during the incomplete combustion of fuels containing carbon, i.e., when the combustion mixture is short of oxygen, or fuel rich. Notable sources include production of coke for subsequent use in steel manufacture, diesel engines, wood burning and even cigarette smoke.

The dioxins and furans are chemically closely related, and their polychlorinated forms are probably among the most toxic chemicals currently found in the environment. They are formed (in very small amounts) in a number of processes, including as byproducts in pesticide and herbicide manufacture, in incineration, and in chlorine bleaching as practised in the pulp and paper industry.

Formaldehyde is produced naturally in the atmosphere in very small amounts as a result of the chemical transformation of natural hydrocarbons emitted by trees, while trace amounts of benzo(a)pyrene and the dioxins and furans are formed in natural forest fires. It should be stressed that the natural sources are very small.

Removal of these toxic chemicals from the atmosphere is largely through the processes of wet and dry deposition. Wet deposition occurs when the compound is brought to the ground in rain or snow, and dry deposition is the process whereby the molecules are brought in contact with the ground by turbulence in the atmosphere. They are then deposited if they stick to the surface as a result of a chemical or physical attraction. The rate at which dry deposition occurs depends very strongly on the form of the chemical in the atmosphere, i.e., whether it is present as a gas or a particle, and also on the size of the particle.

Formaldehyde and, to a lesser extent, benzene, can also be removed from the atmosphere by chemical reactions taking place in the presence of sunlight.

22.2 Ambient Levels Measured

The results from these monitoring activities are presented for each of the urban or industrial centres in which monitoring takes place. It should be noted that not all chemical species are monitored in all locations. The volatile organic compounds (represented here by benzene, dichloromethane and tetrachloroethene) are measured in most places, followed by formaldehyde and benzo(a)pyrene, and then by dioxins and furans. This distribution of activity is directly related to the difficulty and cost of making the measurements. Where available, measurements made by the Ontario Ministry of the Environment and Energy are supplemented with data obtained from Environment Canada.

For each of the chemical species discussed here the monitoring results are contained in *Table 8* which gives the median concentration for each location at which measurements are made. The median is used rather than a simple average, because it is less affected by extreme results (high or low). In most cases the period of record covers 1989 to 1991. For purposes of comparison, the table also contains the Ontario interim standard for the chemical, noting, however, that an interim standard has not yet been set for benzene.

For the dioxins and furans the presentation is somewhat different, because these chemicals are treated as a group, rather than as individual compounds. Although a number of approaches have been discussed in the scientific literature, a simple method has been adopted here, as proposed in the Ontario interim standard. That is to compare the sum of the dioxin concentrations plus one-fiftieth of the sum of the furan concentrations with the interim standard of 30 picograms per cubic metre (one picogram is one millionth of a microgram, which is itself one millionth of a gram).

The results are also shown graphically as bars superimposed on a map of Ontario (*see Figures 13a to 13c*). The base of the bar indicates where the measurements were made, and the height of the bar shows the median concentration.

TABLE 8

Monitoring Results of Selected Airborne Toxics, 1989 to 1991

		Median Concentrations (µg/m³)					
Site	Agency	Benzene		Dichloromethane		Tetrachloroethylene	
Dorset	MOEE	0.35	(20)	N/A		0.00	(20)
Hamilton (29000)	EPS	2.82	(135)	4.76	(109)	1.21	(133)
Hamilton (29102)	MOEE	8.30	(11)	N/A		1.00	(11)
Hamilton (29114)	MOEE	1.05	(10)	N/A		0.40	(9)
North York (Edgar Ave)	EPS	2.32	(122)	1.27	(99)	0.39	(121)
Toronto (Junction Tri)	EPS	2.39	(142)	1.86	(125)	0.61	(141)
Mississauga	MOEE	3.20	(13)	N/A		0.50	(13)
Oakville	MOEE	3.15	(12)	N/A		0.60	(13)
Oshawa	MOEE	2.10	(12)	N/A		1.20	(12)
Stouffville	EPS	1.10	(128)	1.17	(110)	0.19	(128)
London	MOEE	0.40	(21)	N/A		0.10	(20)
Sarnia	EPS	2.15	(153)	0.71	(153)	0.22	(154)
Windsor (Downtown)	EPS	2.79	(204)	1.05	(150)	0.57	(172)
Windsor (College/Prince)	EPS	1.91	(58)	1.21	(58)	0.26	(58)
Windsor (Wright/Water)	MOEE	1.30	(34)	N/A		0.30	(34)
Walpole Island	EPS	0.93	(110)	0.83	(64)	0.14	(94)
Sault Ste. Marie	MOEE	2.10	(27)	N/A		0.30	(27)
Thunder Bay	MOEE	1.80	(30)	N/A		0.10	(32)
Ottawa	EPS	3.86	(132)	1.72	(97)	1.49	(132)

EPS - Environmental Protection Service MOEE Interim Standards: Benzene - Not yet set; Dichloromethane - 1765µg/m³; Tetrachloroethylene - 4000µg/m³

(Figure in bracket represents sample size)

Regarding the results presented here, it should be noted that the concentrations of airborne chemicals in urban and industrial areas are highly variable from point to point, depending particularly on how close the monitoring equipment is to a source or sources. To complicate this, the monitors have been located, in many cases, purposely near to known or suspected sources. Thus relatively high concentrations have been obtained in some cases, but may not represent a real risk to the population of that centre, since the concentrations refer specifically to measurements made close to a specific source. This does not mean, of course, that large emitters of hazardous chemicals will be allowed to continue doing so; rather, the measurements allow the authorities to work with the industry concerned to reduce or eliminate its emissions.

The overall median concentrations of benzene reported here range from 0.35 $\mu g/m^3$ to 8.30 $\mu g/m^3$ with most of the values falling in the range of 1 to 3 $\mu g/m^3$. The lowest value is reported from Dorset, which is what one would expect given the rural nature of the area, with correspondingly little traffic and few other sources. However, the concentration measured at London is also very low, presumably also because the site is located away from major vehicular traffic. The high value for Hamilton (site 29102) results from the fact that this site is located on Beach Boulevard, near major traffic routes, and also positioned such that it will be influenced by emissions from the steel mills. It is therefore reasonable to suggest that benzene concentrations in most urban centres will be in the range of 1 to 3 $\mu g/m^3$, with the exact value depending heavily on the amount of traffic in the vicinity of the site.

These concentrations may be compared with those determined in a major monitoring campaign covering most of the United States. The median benzene concentration found in remote areas was 0.5 $\mu g/m^3$, comparable with Dorset. In rural areas the quoted value was 1.5 $\mu g/m^3$, which is more comparable with the suburban Ontario concentrations (e.g., Stouffville, and one of the Windsor sites). The concentrations reported from this survey for suburban and urban US locations were almost identical, 5.7 and 5.8 $\mu g/m^3$ respectively, which is 50% to 100% higher than the concentrations found for most of the Ontario sites. It should be mentioned again, however, that the exact value found at any site will be influenced directly by how close that site is to high densities of traffic.

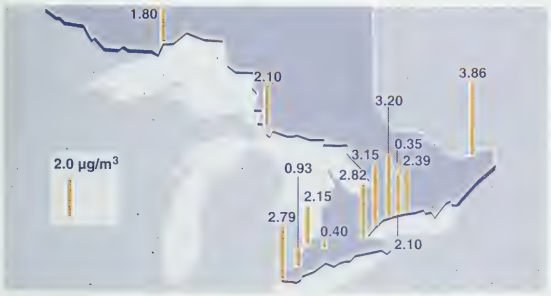
In the case of the chlorinated solvent, dichloromethane, the concentrations are somewhat lower. For a number of the more industrial sites the dichloromethane concentration was found to be about 1 to 1.5 $\mu g/m^3$. The highest median concentration was 4.76 $\mu g/m^3$ measured at the main downtown site in Hamilton. The reason for this higher value for Hamilton is unclear at this time.

Concentrations of dichloromethane in the United States were about 0.2 $\mu g/m^3$ in remote and rural areas, ranging up to 2 $\mu g/m^3$ for suburban sites and 3 $\mu g/m^3$ at urban locations. In a separate survey undertaken in Boston, Chicago, Houston and Seattle the reported median concentrations were in the range 1 to 1.5 $\mu g/m^3$, which is very similar to the results observed for Ontario.

The range of concentrations found for tetrachloroethene in Ontario was much smaller, with the lowest values (0 to 0.1 $\mu g/m^3$) coming from Dorset, London and Thunder Bay, and the highest values (1 to 1.5 $\mu g/m^3$) being found in Hamilton, Oshawa and Ottawa. It is worth noting that in most (but certainly not all) cases, the highest concentrations of all three of the volatile organic compounds discussed here occurred at the same site.

The US measurements did not segregate tetrachloroethene data by class of monitoring location. The overall median concentration for all locations was 1.2 $\mu g/m^3$, which is similar to the highest concentrations reported for Ontario. In the study of 4 cities (i.e., Boston, Chicago, Houston and Seattle) only 30% of the

FIGURE 13(a)
Spatial Distribution of Benzene Levels Across Ontario
(1989 to 1991, Median Concentrations)



measured values were greater than 0.35 µg/m³, which was regarded as the lower limit at which acceptably accurate results were obtained. A detailed presentation of the results for this compound was therefore not given.

Formaldehyde is measured in only three centres in Ontario, namely Ottawa, Toronto and Windsor *(Table 9)*. The median concentrations, based on two years of sampling are 3 µg/m³ for Ottawa, 2.16 µg/m³ for Toronto and 2.05 µg/m³ for Windsor (downtown site). A second site was set up in Windsor in July 1991. Based on six months of data from this site the median concentration was 7.31 µg/m³. It is not yet known whether the much higher concentration observed at this site is representative, or is merely a consequence of the short data record so far available. All of these formaldehyde measurements were made by Environment Canada.

Relatively little data are available on formaldehyde concentrations in other jurisdictions. Average concentrations were determined to be in the range 3.0 to 3.6 µg/m³ in Atlanta during the summer of 1992.

TABLE 9

B(a)P, Dioxins/Furans and Formaldehyde Levels, 1989 to 1991

Site	B(a)P (ng/m³)	Dioxins/Furans (pg/m³)	Formaldehyde[1] (µg/m³)
Dorset	0.0	1.19/0.40	
Toronto		1.06/0.92	2.16
Windsor (Downtown)	0.1	3.34/4.90	2.05
Windsor (College/Prince)	0.0		
Windsor (Wright/Water)	0.1		
Ottawa			3.03
Sault Ste. Marie	0.9		
Thunder Bay	0.1		

Ministry Interim Standards:
B(a)P - 0.3 ng/m³; Dioxins/Furans - 30 pg/m³; Formaldehyde - 65 µg/m³

[1] Environment Canada Data

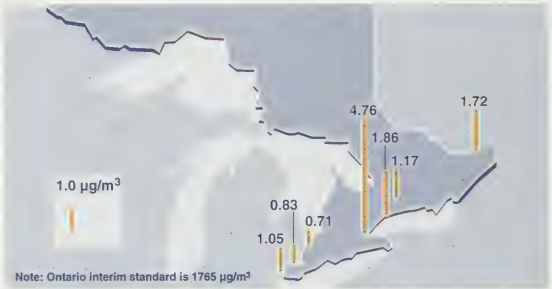
However, it is very difficult, for two reasons, to compare these results with those obtained in Ontario. Firstly, it is expected that the concentrations will be higher in the summer, because ozone is formed by chemical reactions occurring in the atmosphere, which are more likely during the summer. Secondly, it is difficult to compare a median, which is quoted for Ontario, with the mean determined for Atlanta, since the mean is sensitive to the effect of a few very high or very low values. It is worth noting, though, that the authors of the Atlanta study found that their results were consistent with, but somewhat lower than, a few measurements made elsewhere. It is therefore likely that a similar statement can be made for the Ontario results.

At five of the six sites at which benzo(a)pyrene was monitored *(Table 9)*, the median concentration was very low, either 0.0 or 0.1 ng/m³. At the sixth site, in Sault Ste. Marie, the concentration was much higher, at 0.9 ng/m³. This level is actually higher than the Ontario interim standard of 0.3 ng/m³, but it must be pointed out that this site is located adjacent to the Algoma steel plant, where elevated concentrations of PAH likely result from the production of coke used in the steel making process. More recent data for Hamilton (1993) show relatively high levels of B(a)P in the industrial area of Hamilton similar to those levels in Sault Ste. Marie. In a pre-

FIGURE 13(b)

Spatial Distribution of Dichloromethane Levels Across Ontario

(1989 to 1991, Median Concentrations)



liminary study at Dorset, Ontario, benzo(a)pyrene was below the detection limit in every one of the 22 samples collected.

Measurements of benzo(a)-pyrene reported from Bayreuth, in Germany, indicate that concentrations for a series of measurements ranged from about 0.05 ng/m^3 to as high as 0.8 ng/m^3. The results for other areas are similar. For example, benzo(a)pyrene concentrations ranged from about 0.04 ng/m^3 in a remote part of France to as high as 12.8 ng/m^3 at a site in Paris. Concentrations found in Kokkola, Finland, ranged up to about 0.5 ng/m^3. Results reported recently from monitoring in the vicinity of an aluminium smelter in Quebec have indicated a substantial reduction in concentrations over the past seven years, as emission controls have been implemented at the plant, but the observed median concentrations still range from 0.6 to 3.1 ng/m^3, substantially higher than measured in Sault Ste. Marie.

Table 9 gives overall annual average concentration for total dioxins and total furans for the three monitoring sites in Ontario.

It is interesting that the results are very similar for Dorset, a rural site, and Toronto, which is a large urban centre. This is probably a consequence of the large number of sources which can produce dioxins, that is, industrial and traffic related sources produce what is seen in Toronto, while rural activities (such as wood burning for heating) produce the dioxins in Dorset. The concentrations found in Windsor were somewhat higher (by a factor of three or four). This is because there is a concentration of sources in the area. All results are substantially below the current Ontario interim standard, which states that the average dioxin concentration plus one fiftieth of the average furan concentration must be less than 30 pg/m^3.

It is difficult to compare the results obtained in Ontario with data from other areas, because of the very different ways in which concentrations are reported by different agencies. In addition, analytical costs for dioxins and furans are very high, and few agencies have carried out long term monitoring, so that the comparison will generally be with the results of relatively short term studies.

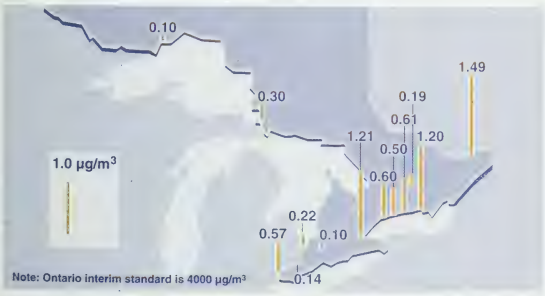
The overall averages found for seven samples collected in Los Angeles between December 1987 and March 1989 were 5.46 pg/m^3 for dioxins and 1.94 pg/m^3 for furans. Individual concentrations for a number of measurements made at different sites in the North Rhine/Westphalia region of Germany ranged between about 0.2 and 6 pg/m^3 for dioxins and 0.6 and 10 pg/m^3 for furans. A long term average concentration of 1.44 pg/m^3 for dioxins and 0.78 pg/m^3 for furans has been reported for Bloomington, Indiana.

It may be concluded from the Ontario monitoring data presented here, and the comparative figures reported by other agencies, that air quality in Ontario compares very well where toxic chemicals are concerned. In almost all instances the concentrations reported for Ontario are similar to, or lower than, those found elsewhere. It is important to reiterate, however, that the actual concentrations found in any monitoring activity depend critically on the precise location chosen for the monitoring instruments. Thus measurements made near a source of the chemical in question (i.e., near a highway, factory, etc.) can be expected to produce higher concentrations than if the measurements are made in a relatively isolated location, even though it may still be within the same urban area. It should be noted that where Ontario interim standards are being exceeded, the Ministry will pursue improved controls on emissions at known sources.

FIGURE 13(c)

Spatial Distribution of Tetrachlorethylene Levels Across Ontario

(1989 to 1991, Median Concentrations)



22.3 Effects

Benzene, formaldehyde, benzo(a)pyrene and the dioxins and furans have all been shown to be carcinogens (capable of causing cancer). Dichloromethane and tetrachloroethene have been shown to be mutagens, i.e., they are capable of causing abrupt or sudden genetic changes within cells. Formaldehyde has been shown to be a mutagen, and is suspected of causing lung tumours.

This means that the chemical compounds discussed here are capable of causing cancer, or of causing changes within a cell, with these changes being reproduced when the cell divides. What is not given here is an assessment of the relative dangers presented by the different compounds, i.e., an answer to questions like

> ***"Should one be more concerned about dioxins at 1 pg/m^3 than about benzene at 2 µg/m^3?"***

and,

> ***"How concerned should one be if the concentration of benzene is 2 µg/m^3?"***

Questions like these are very difficult to answer with any degree of certainty, because, apart from a few tragic occurrences, the only exposure data come from limited laboratory studies. These are carried out with animal species different in size and physiological response from humans, and usually with concentrations of the chemicals that are much higher than those found in the atmosphere. Risk Assessment is the science which seeks to extrapolate these limited exposure results to the real world.

SECTION G

Provincial trends in air quality and emissions

23.0 Trends in Air Quality and Province-wide Emissions

The ambient air quality trends presented in this section are based on direct measurements. These trends are supplemented with trends for annual province-wide emissions from the Ontario Emissions Inventory System (OEIS). Emission estimates are based on the amount and kinds of pollution being emitted by automobiles, industries and other sources, and are largely derived from the best available emission estimation methodologies for a given time period.

Charts and graphs showing emission trends and emission sectors throughout this report are typical of late 1980s emission profiles. Although the total annual emission of each air pollutant will change from year to year, the ranking of industrial sectors in terms of their emission contribution remains fairly constant.

For stationary sources, SO_2, NO_x, VOC, CO and particulate emission estimates are obtained mainly from mass balance calculations or computation using standard emission factors.

For mobile sources (gasoline and diesel powered motor vehicles), CO, NO_x and volatile organic compounds (VOC) emission estimates were based upon vehicle kilometer tabulations and emission factors from the Mobile 4.1c transportation model developed by Environment Canada. It is anticipated that with the revision of the Mobile 4.1c into Mobile 5.0c later this year, the emission estimation for mobile sources will increase.

It should be noted, however, that the methods currently in use worldwide to obtain emission estimation from the sources may have varying degrees of uncertainty, depending on the quality of available source information and the accuracy of the emission estimation methodologies that are applied.

Because of changes that have occurred in ambient monitoring measurement methodology and the change over time in the geographical distribution of monitors, it is dif-

FIGURE 14(a)

Long Term Trend for Pb in TSP

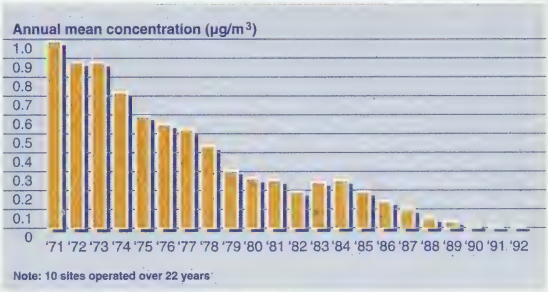


FIGURE 14(b)

Long Term Trend for SO_2

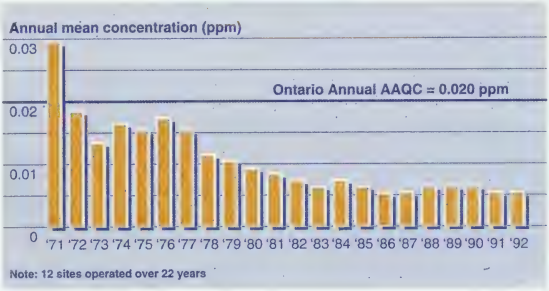


FIGURE 14(c)
Long Term Trend for CO

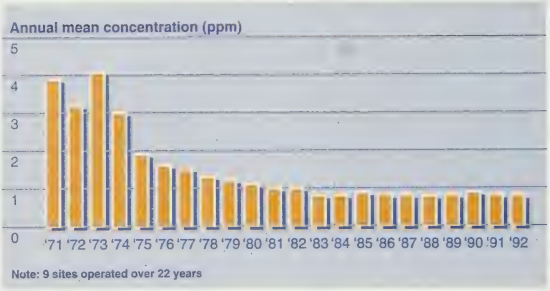


FIGURE 14(d)
Long Term Trend for TSP

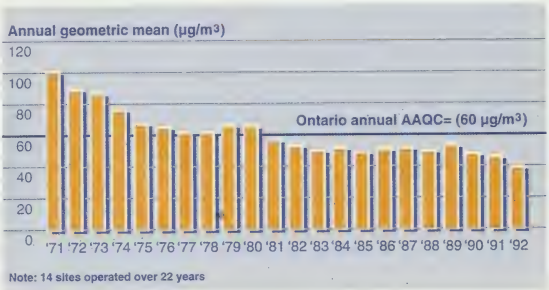
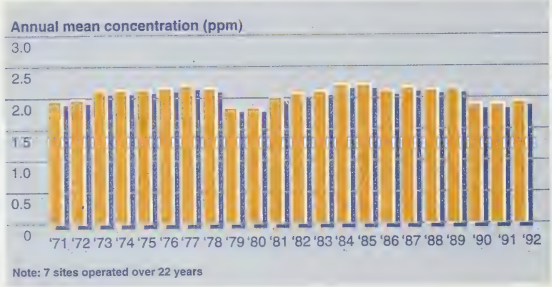


FIGURE 14(e)
Long Term Trend for THC



ficult to provide ambient trends going back twenty-two years for all pollutants; yet, it is important not to lose sight of some of the earlier progress that was made in air pollution control in Ontario. The pollutants which can be displayed are Pb, SO_2, CO, TSP, THC and SP. *Figures 14a to 14f* show the 22-year trend in the composite average of annual means for Pb, SO_2, CO, TSP, THC and SP at monitoring sites which have operated continuously during the past twenty-two years. Over this 22-year period, Pb clearly shows the most impressive decrease of 99%. Significant decreases are also evident for SO_2 (83%), CO (79%) and TSP (61%). THC and SP show no significant trend over the 22-year period. *Figures 14g and 14h* show the 18-year trend in NO_2 and NO_x across Ontario. NO_2 and NO_x levels have decreased by 22% and 46% respectively over the 18-year period. O_3 shown in *Figure 14i* shows year to year variability over a 14-year period.

23.1 10-Year Trend in Sulphur Dioxide (SO_2)

The 10-year trend in mean ambient SO_2, 1983 to 1992, is presented in *Figure 15* and *Table 10a* for twenty-five sites which possess a continuous ten-year record. Annual mean ambient SO_2 levels have improved by about 20% over the 10-year period (83% over the 22- year period, *(see Figure 14b)*. The majority of monitors in Ontario's urban centres meet the provincial 1-hour objective (0.25 ppm). Of the fifteen stations which exceeded the provincial 1-hour SO_2 AAQC in 1992, 13 were located in the Sudbury basin area. The Inco and Falconbridge smelting operations in the Sudbury area are responsible for the large number of 1-hour exceedances there.

The geographical distribution of the annual mean SO_2 concentrations

indicates that the centres with the stronger emission sources such as Hamilton, Sudbury and Sarnia record the highest annual SO_2 levels, *(see Figure 16)*.

Most of the SO_2 emissions are due to large point sources in Ontario. As shown in the SO_2 emission trend plot *(Figure 17)*, smelters contribute about half of the sulphur dioxide emissions. The SO_2 emissions from smelters have dropped 80% since 1970. With the introduction of tighter emission controls and use of low sulphur fuel, province-wide SO_2 emissions were reduced by 73% compared to 1970 and about 30% from 1983. The relatively lower SO_2 emissions in 1978, 1979, 1982 and 1983 resulted from production shutdowns/decreases at the Sudbury smelters. The Countdown Acid Rain program initiated in 1986 has led to some of the SO_2 emission reductions seen in 1990 through 1992. The 1992 SO_2 emissions from electrical utilities was 157 kilo-tonnes. This is below the 1994 Countdown Acid Rain limit of 175 kilo-tonnes. The emissions from smelters were also reduced with the commissioning of the first phase of their SO_2 abatement program. (See Section 26.1 for a case study analysis of SO_2 levels in Sudbury).

23.2 10-Year Trend in Carbon Monoxide (CO)

The trend in mean annual CO concentrations at locations which possess a 10-year record is shown in *Table 10b* and is summarized for the province in *Figure 18*. From 1983 to 1992 mean ambient CO levels have remained relatively constant over the 10-year period. The geographical distribution of the 1-hour maximum and 8-hour maximum ambient CO concentrations is displayed in *Figures 19 and 20*, respectively. The Mission monitoring site in downtown Toronto recorded the maxi-

FIGURE 14(f)

Long Term Trend for SP

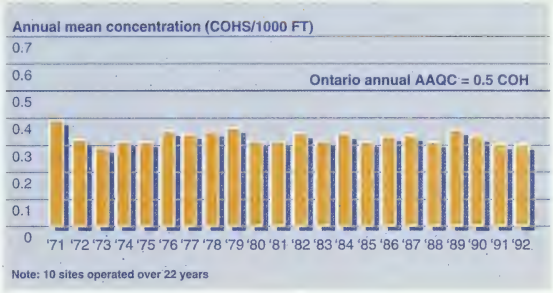


FIGURE 14(g)

Long Term Trend for NO_2

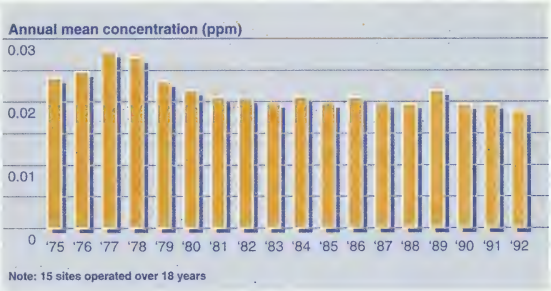


FIGURE 14(h)

Long Term Trend for NO_x

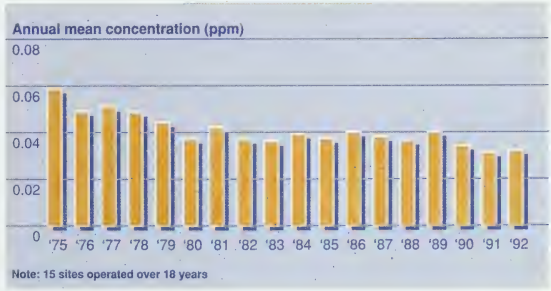


FIGURE 14(i)

Long Term Trend for O_3

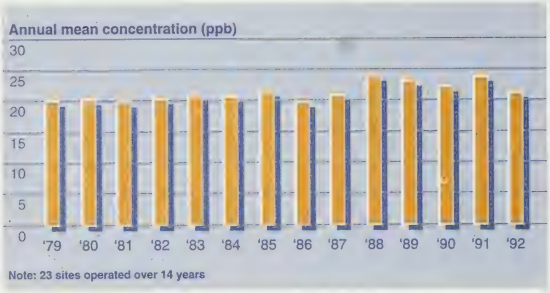


FIGURE 15

10-Year Trend for SO_2

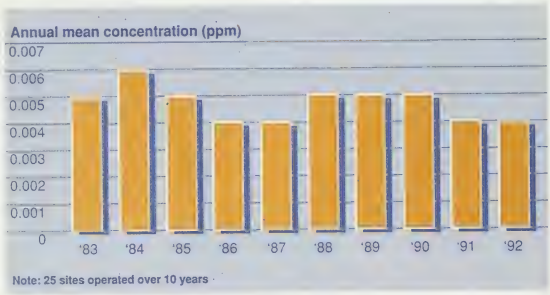
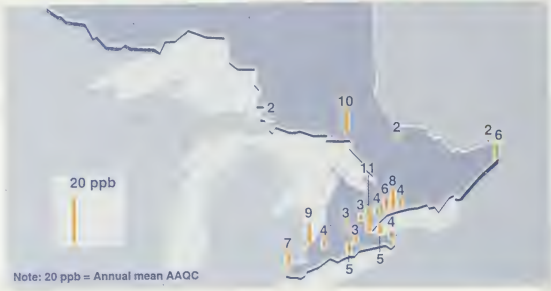


FIGURE 16

Sulphur Dioxide (SO_2), Annual Mean Concentration, 1992



mum levels for both the 1-hour and eight hour averaging periods. This is directly related to vehicle emissions of CO. *(See section 26.2 for a case study analysis of the impact of vehicle-related pollutants on air quality levels in downtown Toronto).*

The transportation sector accounts for about 75% of carbon monoxide emissions. Estimates of carbon monoxide emissions from 1983 to 1992 *(Figure 21)* show little change in total emissions until 1986 with a slow steady decrease since that time. Despite an increase in vehicle kilometers travelled over the last decade, *(Figure 22)*, emissions from the transportation sector have decreased by about 39% through better emission controls.

23.3 10-Year Trend in Nitrogen Dioxide (NO_2) Nitric Oxide (NO) and Oxides of Nitrogen (NO_x)

The 10-year trend in the annual average NO_2, NO and NO_x concentration at selected Ontario cities is summarized in *Tables 10c, 10d and 10e* respectively. NO_2 levels have remained relatively constant over the 10-year period with the exception of 1989 to 1992 which shows a 14% drop *(Figure 23)*. NO and NO_x levels over the same 10-year period show a little more year to year variation, and more than a 20% drop is evident between 1989 to 1992 *(Figures 24 and 25)*.

The geographical distribution of the 1-hour maximum NO_2 concentration confirms as one would expect that the highest levels of NO_2 are recorded in the larger urban centres across Ontario *(Figure 26)*. This is because vehicles are the primary emitter of NO_x.

The emission of NO_x showed little variation from years 1982 to 1989 *(Figure 27)*. However, with the introduction of new vehicle emission

standards in 1988, there was a downward trend of emissions from the transportation sector from 1989 onwards even with the increase in vehicle kilometers travelled *(Figure 22)*. The transportation sector contributes about 60% of the total nitrogen oxide emissions *(Figure 27)* and the new vehicle emission standards have resulted in an overall decrease in emissions of more than 10% from 1989 to 1992.

23.4 10-Year Trend in Ozone (O_3)

The 10-year trend in mean annual ozone levels and number of exceedances of the provincial 1-hour AAQC (80 ppb) for 23 ozone sites (1982-1991) are displayed in *Figure 28 and Table 10f*. The relatively high ozone concentrations in 1983, 1988 and 1991 are likely attributed in part to hot, dry stagnant summertime conditions (high temperatures and strong solar insolation). The interpretation of the 10-year ozone trend is difficult due to the compounding factors of meteorology and emission changes. Just as the increase in 1983, 1988 and 1991 is attributed in part to the meteorological conditions, the relatively lower ozone concentrations in 1989, 1990 and now 1992 are likely due, in part, to meteorological conditions being less favourable for ozone formation. (*See Section 28.0* for a detailed ozone analysis).

There is little variation in the VOC emission trend for the last 10 years (Figures 29 and 30). As a result of new vehicle emission standards and the economic slow-down, emissions from the transportation and industrial processes showed a small decrease from 1989 to 1992.

It should be noted that fugitive, forest fire and natural VOC emissions were not considered in this emission trend. It is estimated that fugitive sources may increase the provincial emission total by 5%. Recent study indicates that natural

FIGURE 17

Ontario Sulphur Dioxide Emission Trend, 1970 to 1992

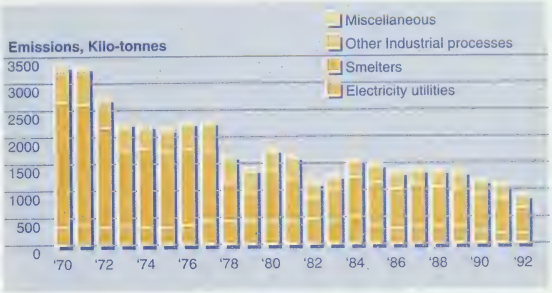


FIGURE 18

10-Year Trend for CO

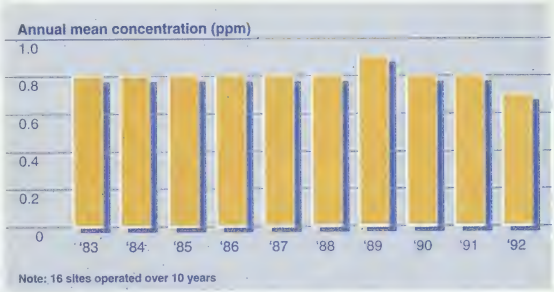


FIGURE 19

Carbon Monoxide (CO), 1-Hour Maximum, 1992

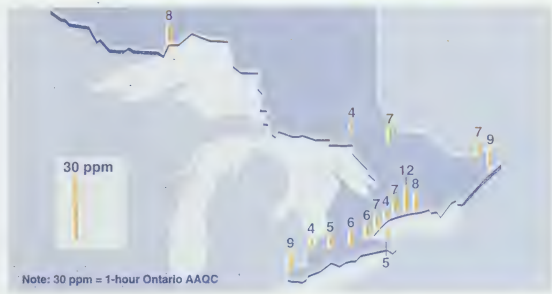


FIGURE 20

Carbon Monoxide (CO), 8-Hour Maximum, 1992

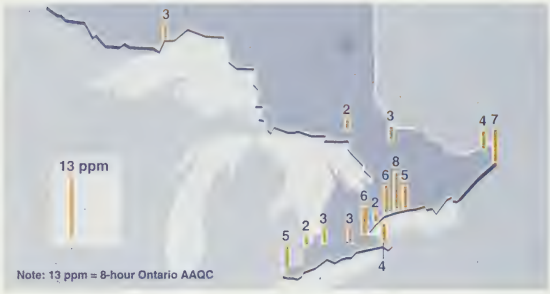


FIGURE 21

Ontario Carbon Monoxide Emission Trend, 1983 to 1992

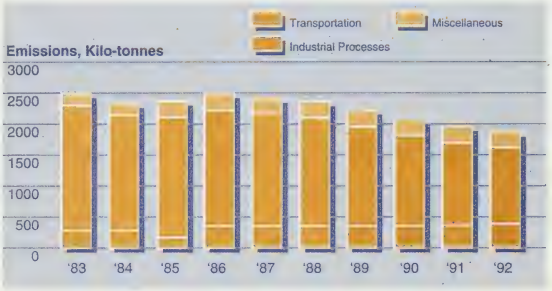
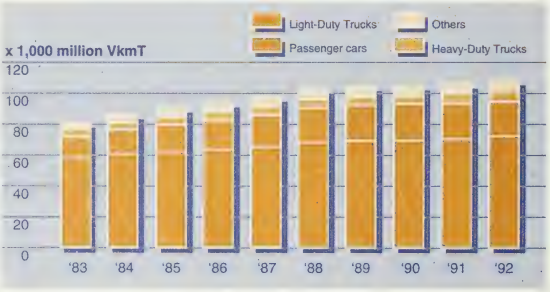


FIGURE 22

Ontario Vehicle-Kilometers Travelled, 1983 to 1992



source emissions may be as high as three times the anthropogenic sources.

The introduction of lower Reid Vapour Pressure (RVP) gasoline (from 11.5 psi to 10.5 psi) beginning in 1989 for the summer months has resulted in an annual reduction of the provincial VOC emissions by about 1.6% *(Figure 31)*. Similar or larger reductions in the RVP have been introduced for states south of Ontario since 1989. As a result, the reduction in VOC emissions in 1992 from the Ontario transportation sector, including gasoline handling, has been estimated to be about 4.5% *(Figure 31)*.

The impact of VOC emissions, as a precursor, on ozone production is difficult to see in the trend of O_3 for 1989 to 1991. The number of O_3 exceedances during the 1989 to 1991 period was comparable to or higher than the results during 1983 to 1987 when the RVP was 11.5 psi. Any trend in ozone during 1989 to 1992 can be attributed mostly to meteorological variability as was the case in 1988.

23.5 10-Year Trend in Suspended Particles (SP)

The trend in mean annual SP concentration at selected Ontario cities is shown in *Table 10g* and summarized for the province in *Figure 32*. Fine particulate, as determined by SP, has remained relatively constant over the 10-year period 1983-1992. However, as previously stated, the 24-hour AAQC for suspended particles was the second most frequently exceeded AAQC during 1992.

23.6 10-Year Trend in Total Reduced Sulphur (TRS)

Table 10h shows the ten-year trend in mean annual TRS for selected Ontario cities while *Figure 33*

shows the provincial trend with a minimum composite mean in 1985 and a general decreasing trend over the last five years. The minimum in 1985 is due to production shut-downs/decreases at the kraft pulp mill in Cornwall and to the use of monitors which underestimated TRS levels in Fort Frances.

Figure 34 shows the number of exceedances of the TRS 1-hour pulp mill criterion (27ppb) at monitoring sites across Ontario. As expected the highest number of exceedances are recorded in communities which have kraft pulp mills, (i.e., Fort Frances, Cornwall, Thorold, Terrace Bay, Thunder Bay, Smooth Rock Falls, Red Rock and Marathon). On occasion, TRS 1-hour exceedances are recorded in Windsor, Hamilton, Oakville, Mississauga and Sault Ste Marie. Elevated levels of TRS in these locations are usually due to iron and steel or refinery operations.

23.7 10-Year Trend in Particulate Matter (TSP)

The trend in mean annual TSP concentrations at 31 sites which possess a 10-year record is shown in *Table 10i* and summarized for the province in *Figure 35*. Particulate levels across Ontario have improved by 17% over the 10-year period 1983 to 1992. However, as stated earlier, 63% of the stations measuring for TSP exceeded the 24-hour AAQC at least once and 7% exceeded the annual criterion. Even though particulate levels province-wide are decreasing, levels at some sites in urban centres such as Hamilton, Windsor and Niagara Falls continue to exceed the Ontario AAQC. The spatial distribution of annual TSP levels is shown in *Figure 36* for monitoring sites across Ontario.

FIGURE 23
10-Year Trend for NO_2

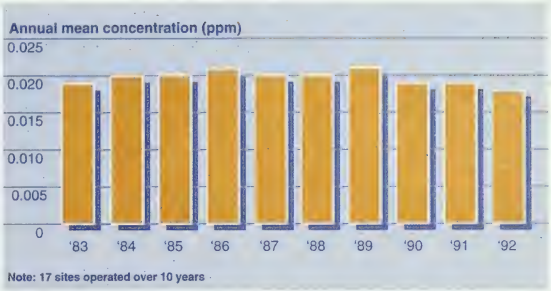


FIGURE 24
10-Year Trend for NO

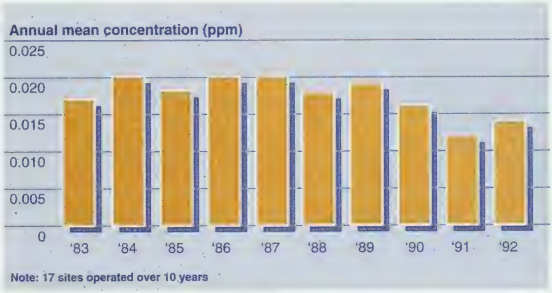


FIGURE 25
10-Year Trend for NO_x

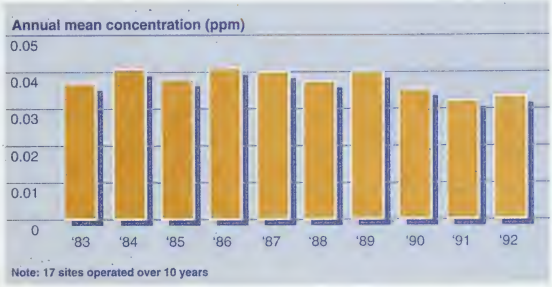


FIGURE 26

Nitrogen Dioxide (NO_2), 1-Hour Maximum, 1992

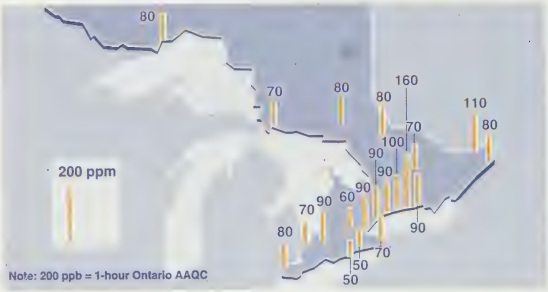


FIGURE 27

Ontario Nitrogen Oxides Emission Trend, 1983 to 1992

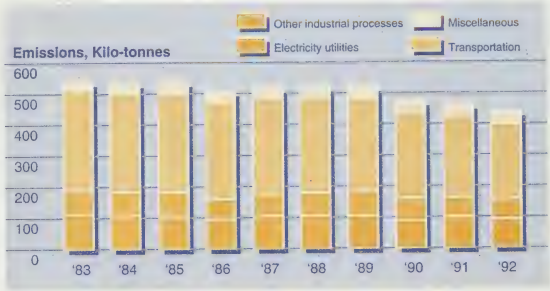
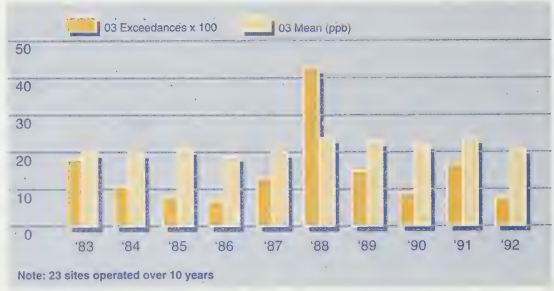


FIGURE 28

10-Year Trend for Ozone



The particulate emissions showed a slight upward trend from 1983 to 1989 and a downward trend from 1989 onwards *(Figure 37)*. The emission reductions between 1989 and 1992 were from the industrial processes and other sectors. Emissions from transportation remained stable from 1989 to 1992.

Particulate emissions from fugitive sources and forest fires were not included in the emission trend analysis. The emissions from forest fires vary from year to year and can be several times higher than anthropogenic sources. Contributions from fugitive sources such as road dust, construction and surface erosion have not yet been assessed. Since fugitive emissions from sources such as entrained road dust can be the dominant source of ambient TSP levels, the trend in measured TSP values would not necessarily follow the emission trend.

23.8 10-Year Trend in Lead (Pb)

Pb levels in air have improved significantly over the past 10-year period as shown in *Figure 38*. The ambient Pb levels represent general urban conditions predominantly reflecting automotive sources. The trend at selected Ontario cities is shown in *Table 10j*. Pb levels have declined by 99% during the period 1983 to 1992. This decline is due to the increased use of unleaded gasoline in catalyst-equipped cars and the reduced Pb content in leaded gasoline. Pb emissions from gasoline use have been effectively eliminated because the addition of Pb to gasoline was prohibited after December 1, 1990.

As mentioned earlier, the highest Pb concentrations are measured in the vicinity of secondary Pb processing plants. These plants tend to be located in urban areas and therefore remain an environmental concern. Emissions from these

plants are being closely monitored. *(See Section 26.3 for a case study on lead levels near a secondary lead plant in Toronto).*

23.9 10-Year Trend in Manganese (Mn) in TSP

Table 10k provides the ten-year trend for average Mn concentrations at the stations where a 10-year record exists. *Figure 39* summarizes the data for the province. Mn levels have increased by 39% over the last 10 years. In order to raise the fuel octane level in the absence of lead, a manganese compound was added to gasoline. This manganese compound is a contributing factor for the observed increase in Mn levels in Ontario. It should also be noted that emissions from the iron and steel industry contribute to elevated Mn levels found in particulates. These levels, however, are well below the provincial AAQC.

23.10 10-Year Trend in Copper (Cu) in TSP

The trend in mean ambient Cu levels is shown in *Table 10l* and summarized for Ontario in *Figure 40*. Cu levels have decreased by 70% over the last 10 years. It should be noted that in the earlier years the copper data may have been affected by the contamination from the copper windings of the Hi-vol motor. No attempt has been made to correct the data.

23.11 10-Year Trend in Iron (Fe) in TSP

The trend in mean annual Fe concentrations is shown in *Table 10m* and is summarized for the province in *Figure 41*. Fe levels have remained constant over the last 10 years.

FIGURE 29

Ontario VOC Emission Trend, 1983 to 1992

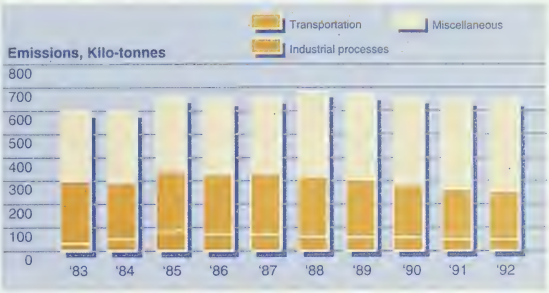


FIGURE 30

Ontario VOC Emissions by Sectors

(Man-Made Emissions, Late 1980s)

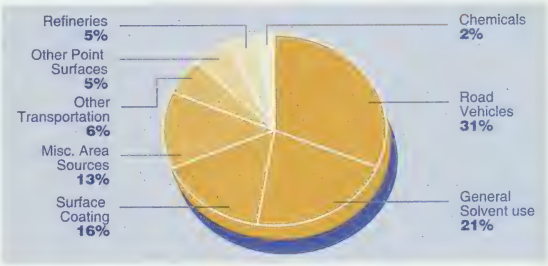
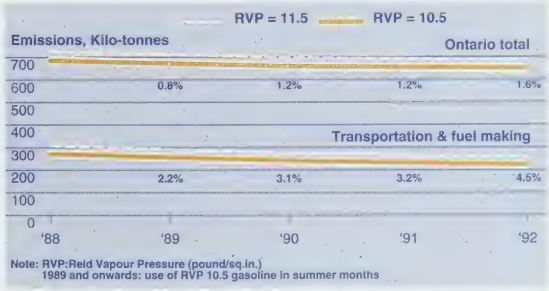


FIGURE 31

Reduction in Ontario VOC Emission Due to Lower Gasoline RVP in Summer



Note: RVP:Reid Vapour Pressure (pound/sq.in.)
1989 and onwards: use of RVP 10.5 gasoline in summer months

FIGURE 32
10-Year Trend for SP

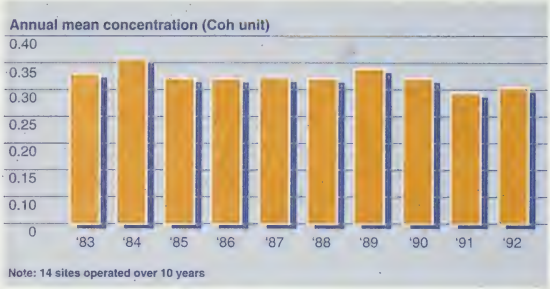


FIGURE 33
10-Year Trend for TRS

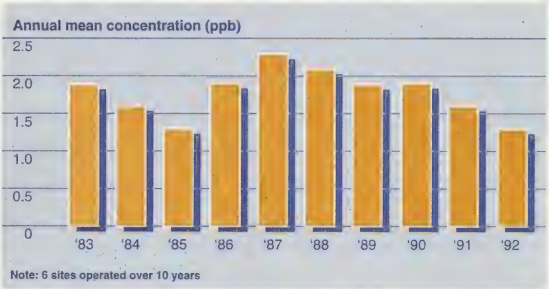
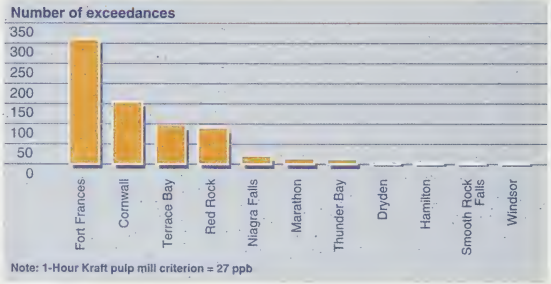


FIGURE 34
Total Reduced Sulphur (TRS)
Exceedances of 1-Hour Kraft Pulp Mill Criterion in Ontario, 1992



23.12 10-Year Trend in Nitrate (NO_3^-) in TSP

The trend in mean annual nitrate at locations which possess a 10-year record is shown in *Table 10n* and summarized for the province in *Figure 42*. The nitrate variability from year to year is largely related to meteorological variability and changes in emissions on a regional scale since nitrate is primarily the result of medium and long range transport of air pollution.

23.13 10-Year Trend in Sulphate (SO_4^{2-}) in TSP

The trend in mean annual sulphate levels is shown in *Table 10o* and summarized for the province in *Figure 43*. As in the case of nitrate, the sulphate variability may also be explained by meteorological variability and changes in emissions on a regional scale.

24.0 Ambient Air Quality Comparison - Southern Ontario Vs Northern Ontario

In the following section, the air quality levels at various industrial and urban centres of Ontario are discussed. Special attention is given to southern versus northern Ontario in view of the difference in distribution of industries in these two regions. Furthermore, southern Ontario is more often affected by long range transport of pollutant species from the U.S.

Ambient air quality concentrations for selected criteria pollutants (SO_2, CO, NO_2, O_3 and TSP) were compared for southern Ontario versus northern Ontario for 1992. Data from representative monitoring sites (excluding sites which are biased by local sources) in Sudbury, North Bay, Sault Ste Marie and Thunder Bay were used to represent northern Ontario while data from representa-

tive monitoring sites (excluding sites which are biased by local sources) in Windsor, London, Hamilton and Toronto were used to represent southern Ontario.

The range of annual means and the range of 1-hour, 8-hour and 24-hour maximum concentrations are presented in *Table 11* for northern versus southern Ontario for 1992. Also included in the table is the composite number of 1-hour AAQC exceedances for SO_2, CO, NO_2 and O_3 and the percentage of exceedances for the 24-hour TSP AAQC.

For SO_2, there is a much larger range in 1-hour maximum concentration in northern Ontario; and also, there were 8 exceedances of the 1-hour SO_2 AAQC recorded in northern Ontario and none recorded in southern Ontario during 1992. SO_2 criterion exceedances in northern Ontario primarily reflect the presence of the INCO and Falconbridge smelter operations for the Sudbury site.

For CO, the levels in southern Ontario are significantly higher. The annual means are approximately 5 times greater than the annual means in northern Ontario. The range of 1-hour and 8-hour maximum values are also higher than those of northern Ontario *(Table 11)*. Elevated carbon monoxide levels are strongly related to automobile use and emissions from combustion sources in high density urban areas.

For NO_2, the composite mean for southern Ontario is 0.023 ppm compared with 0.010 ppm for northern Ontario. The 24-hour maximum concentrations in southern Ontario are also significantly higher than those of northern Ontario *(Table 11)*. Similar to CO, the presence of high temperature combustion sources including automobiles, power plants and incinerators in high density urban areas account for elevated levels of this contaminant.

FIGURE 35

10-Year Trend for TSP

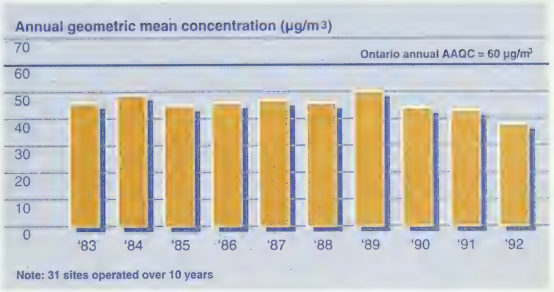


FIGURE 36

Total Suspended Particulates (TSP), Annual Geometric Mean, 1992

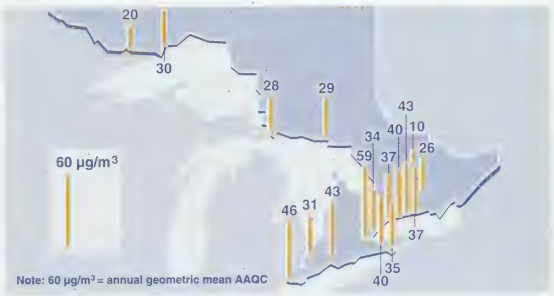


FIGURE 37

Ontario Particulate Emission Trend, 1983 to 1992

FIGURE 38

10-Year Trend for Pb in TSP

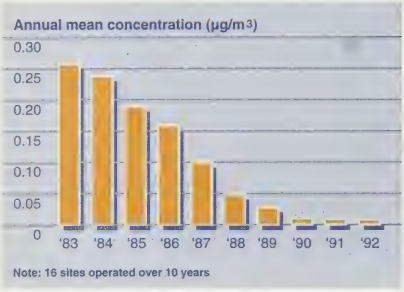


FIGURE 39

10-Year Trend for Mn in TSP

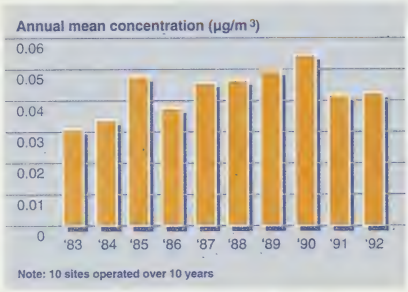


FIGURE 40

10-Year Trend for Cu in TSP

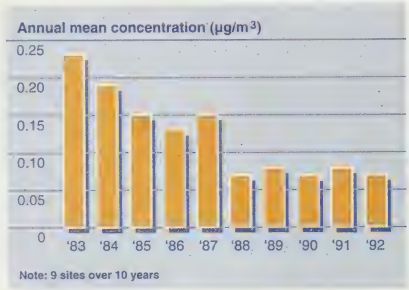


FIGURE 41

10-Year Trend for Fe in TSP

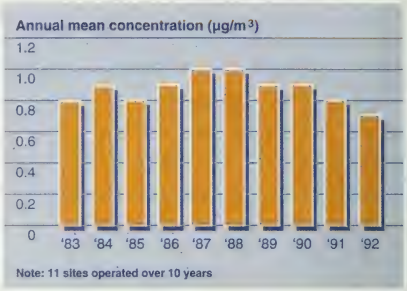


FIGURE 42

10-Year Trend for NO_3^- in TSP

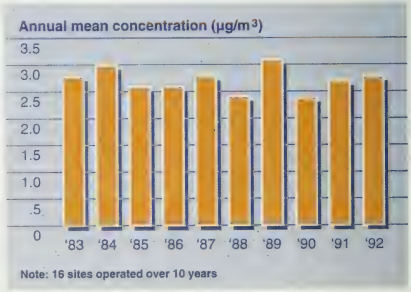


FIGURE 43

10-Year Trend for SO_4^{2-} in TSP

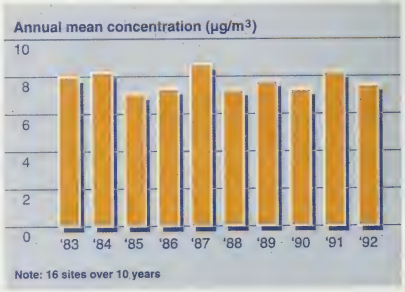


TABLE 11

Comparison of Air Quality Levels in Northern Ontario Versus Southern Ontario, 1992

	SO_2 (ppm)		CO (ppm)		NO_2 (ppm)		O_3 (ppb)		TSP (µg/m³)	
	South	North	South	North	South	North	South	North	South	North
Range of Annual Mean	0.004 - 0.008 (0.006)	0.000 - 0.004 (0.002)	0.6 - 1.9 (1.1)	0.1 - 0.2 (0.2)	0.018 - 0.031 (0.023)	0.009 - 0.011 (0.010)	17 - 20 (19)	17 - 25 (22)	43 - 59 (48)	28 - 30 (29)
Range of 1-Hr Max.	0.05 - 0.13 (0.08)	0.02 - 0.46 (0.16)	6 - 12 (8)	4 - 8 (6)	0.08 - 0.11 (0.09)	0.07 - 0.08 (0.08)	94 - 125 (112)	59 - 96 (80)	N/A	N/A
Range of 8-Hr. Max.	N/A	N/A	3 - 8 (5)	2 - 3 (2)	N/A	N/A	N/A	N/A	N/A	N/A
Range of 24-Hr. Max	0.02 - 0.04 (0.02)	0.01 - 0.04 (0.02)	N/A	N/A	0.04 - 0.08 (0.05)	0.03 - 0.04 (0.03)	59 - 73 (66)	50 - 70 (60)	144 - 209 (166)	90 - 129 (111)
# Exceedances	0	8	0	0	0	0	110	43	(3%)	(1.0%)

Figures in brackets are the composite mean. Geometric means are used for TSP.

For O_3, the range of annual means in northern Ontario is higher than that reported for southern Ontario; however, the opposite is true for the 1-hour and 24-hour maximum concentrations. The composite number of exceedances of the provincial 1-hour AAQC is 110 in southern Ontario compared to 43 in northern Ontario. Long range transport is a significant contributor to elevated ozone levels across Ontario. *(See Section 28.0 for further discussion on ozone in Ontario)*

TSP levels in southern Ontario urban centres are significantly higher than the levels recorded in northern Ontario urban centres. In 1992, the southern Ontario composite geometric mean of TSP was 48 µg/m³ compared to a northern Ontario composite geometric mean of 29 µg/m³. Also the percentage of exceedances of the 24-hour AAQC for TSP and the range in 24-hour maximum values in southern Ontario were higher than those found in northern Ontario.

25.0 Ambient Air Quality Comparison in Selected Cities Around the World

In the "Air Quality in Ontario, 1990" report, ambient air quality levels for SO_2, NO_2, CO, O_3 and TSP were compared for six North American cities using 1989 data. In the 1991 report, the comparison (still using 1989 data) was expanded to include other cities of the world. For this report, we have compared 1991 concentrations of up to six pollutants in 18 major cities which provided data *(Figure 44)* and for the first time, inhalable particulate (IP) has been included.

The inter-city comparisons are referenced to ambient air quality criteria for Ontario (AAQC), the Canadian National Air Quality Objectives (NAAQC) and the United States Environmental Protection

FIGURE 44

Location of Cities Used in International Air Quality Comparison

FIGURE 45(a)

Annual SO_2 Averages at Monitoring Sites in Selected Cities, 1991

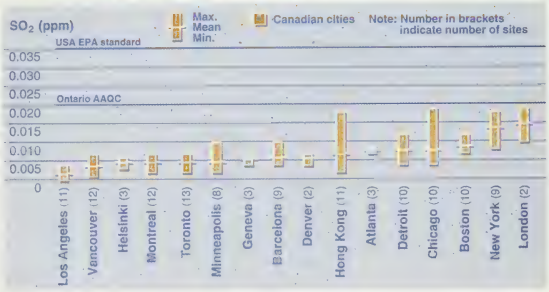
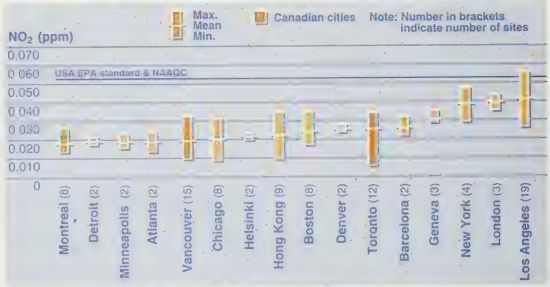


FIGURE 45(b)

Annual NO_2 Averages at Monitoring Sites in Selected Cities, 1991



Agency standards (US EPA).

Most literature comparing air quality for world cities is published by the United Nations Environment Programme (UNEP) and the World Health Organization (WHO), using data from the Global Environment Monitoring System (GEMS/Air) network. The GEMS/Air monitoring project began in 1973 and has gradually increased to more than 50 participating countries and approximately 200 monitoring sites.

In most cities, there are three GEMS/Air monitoring stations: one residential, one commercial and one in an industrial area. It is believed that the data from these stations permit a reasonable evaluation of minimum and maximum pollutant levels, and of long-term trends.

In early 1993, the Ministry requested ambient air quality data from 32 North American and international cities. A total of 20 cities in 10 countries responded with air quality information. Of the 20 cities which responded, 18 provided data that could be used in the comparison with Toronto's air quality. For our 1992 air quality report, we used data from all available sites operating during 1991 within the metropolitan area of each city. The use of all available data was probably more representative of average city air quality than data from only one site. With this approach the proximity of each monitoring site to local sources affecting air quality is not always known. For example, the Toronto composite mean includes a station in an "urban canyon" where there is high density, slow moving traffic. At this site, the levels of vehicle-related pollutants are the highest in Ontario.

A summary of the annual average SO_2 concentrations for 16 cities is presented in *Figure 45a:* The data show that SO_2 did not exceed the Ontario AAQC in any city; Toronto was at the lower end of the range of

means reported. During the early to mid 1970s in Toronto there was a shift to the use of cleaner burning fuels for space heating and in industry. As a result, SO_2 in Toronto during this period gradually decreased to levels well below the provincial AAQC. Of the 16 cities reporting ambient SO_2 in 1991, New York, and London recorded the highest annual composite means.

Annual average levels of NO_2 were relatively low in each of the 16 cities presented in *Figure 45b*, and did not exceed the U.S. EPA standard or the Canadian NAAQC (Ontario does not have an annual AAQC for NO_2). The three highest 1991 composite averages were recorded in Los Angeles, London and New York; these levels were largely attributed to motor vehicle emissions.

A comparison of the 1991 CO levels in 15 cities is presented in *Figure 45c*. The data are reported as 1-hour and 8-hour maximum values. These values represent "worst case" air quality and indicate the potential for air pollution incidents. *Figure 45c* shows that CO in Toronto is somewhat higher than that in other cities selected for comparison. The highest 8-hour maximum, widely used for comparison because it is the more restrictive limit, was recorded in Los Angeles, followed by Barcelona and Minneapolis then Toronto. The Toronto data include an urban street canyon site, described earlier, which has much higher CO levels than any other station in Toronto. The significantly higher 1-hour maximum CO levels measured in Los Angeles, Denver, and Toronto, as compared to the other cities, are largely attributed to vehicle emissions, local geography and meteorology.

O_3 is a pollutant which is not a direct reflection of emissions from a city, but rather, a secondary pollutant; in Ontario, a major cause of el-

FIGURE 45(c)

Comparison of CO Levels at Monitoring Sites in Selected Cities: 1991

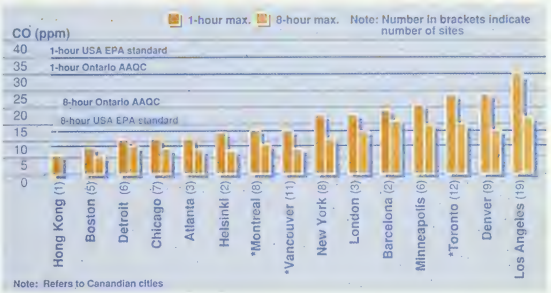


FIGURE 45(d)

Max. 1-Hour Average O_3 Levels at Monitoring Sites in Selected Cities, 1991

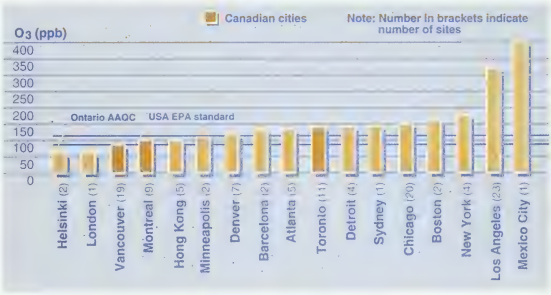
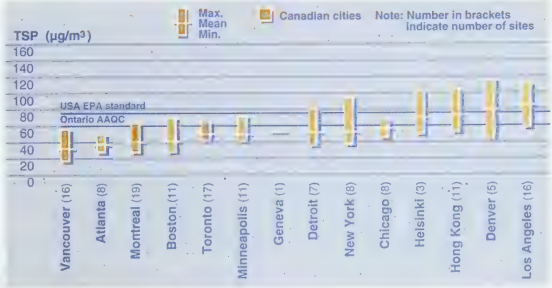


FIGURE 45(e)

Annual TSP Averages at Monitoring Sites in Selected Cities, 1991



evated ozone is long range transport from outside the province. The maximum 1-hour O_3 levels in selected cities for 1991 are shown in *Figure 45d*. Of the 17 cities listed, Toronto was in the middle of the group. Mexico City and Los Angeles both recorded 1-hour maximum cocentrations well above those in all other cities.

TSP, a good indicator of urban air pollution problems in large cities, refers to airborne particles with a diameter between 0.1 and 100 microns. As depicted in *Figure 45e*, the 1991 TSP annual geometric mean concentrations in 14 selected cities indicate that Toronto's composite mean was just below the Ontario AAQC. However, in comparison to cities such as Los Angeles, Denver, Hong Kong and Helsinki, TSP in Toronto is much lower.

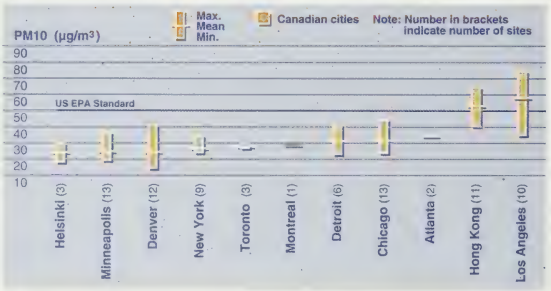
IP is that fraction of total suspended particulate comprising particles with a diameter of 10 microns or less. As mentioned in *Section 15.0* of this report, IP has been determined to be the particle size which is most likely to be inhaled and deposited into the thoracic region of the lung. The highest composite annual arithmetic mean was recorded in Los Angeles and Hong Kong *(see Figure 45f)*. Levels of IP in Toronto were at the lower end of the range for the 11 cities reporting.

26.0 Air Quality in Selected Problem Areas within Ontario

In the "Air Quality in Ontario 1991" report, air quality in selected problem areas of Ontario was discussed in detail in four case studies i.e., particulates in Hamilton, CO in downtown Toronto, TRS in Fort Frances and SO_2 in Sudbury. Over the 1991 to 1992 period, it is to be noted that particulate levels in Hamilton and carbon monoxide levels in downtown Toronto have shown slight improvement while TRS concentrations in Fort Frances have increased slightly. The description of these case studies found in the 1991 report remain unchanged. This year's report will focus on updating the 1991 case study analysis of SO_2 in Sudbury as well as a discussion of two new case studies i.e., the impact of vehicle emissions on daily air quality levels in downtown Toronto and lead levels in the vicinity of a secondary lead processing plant in Toronto.

FIGURE 45(f)

Annual PM10 Averages at Monitoring Sites in Selected Cities, 1991



26.1 CASE STUDY 1 -- Sulphur Dioxide in Sudbury

In the city of Sudbury, sulphur dioxide (SO_2) has been the contaminant of greatest concern since the Ministry began its routine monitoring in the early 1970s. The SO_2 monitoring network extends well beyond Sudbury's city limits and regional municipality to distances as far as 100 km to measure the impact of SO_2 emissions from the Inco and Falconbridge smelting operations. Changes have taken place in the SO_2 monitoring network throughout this time period. The majority of these changes consisted of relocating the monitoring stations closer to the city and in the vicinity of the smelters because of significant improvements in air quality outside of the Sudbury Region due to decreasing smelter emissions and greater dispersion due to Inco's tall stack at Copper Cliff.

The data used in this study were obtained from the SO_2 monitoring stations located directly within the city, thus representing concentrations to which the majority of the population is exposed. Monitoring stations in towns within the Sudbury basin area but outside of the city boundaries have on occasion recorded higher annual SO_2 levels.

The graph displayed in *Figure 46* shows the measurable improvements in the quality of Sudbury's air for SO_2 over the years.

In a recent report (MOE 1990), a correlation was attempted between Inco's SO_2 emissions in tonnes/year and the annual mean SO_2 levels for Ash Street from 1969 to 1989. The results of this regression analysis statistically showed little correlation between these two parameters. This suggests that annual mean SO_2 levels in the Sudbury area are more strongly influenced by the frequency and intensity of short-term fumigations which in turn are de-

pendent on the year to year meteorological variability.

The purpose of Inco's "tall" stack erected in 1972 was to release pollutants at a greater height, thus carrying the pollutants further from the source and dispersing them over a wider area, resulting in lower annual means and fewer exceedances of the provincial AAQC. Although the tall stack did not completely eliminate the problem of short-term fumigations, noticeable improvements have been observed.

The SO_2 emissions reduction program imposed on both Inco and Falconbridge through the Ministry control orders is also responsible for the improvements realized in the frequency and severity of short term fumigations. Under this program, smelter emissions are curtailed through production cuts prior to the onset of adverse dispersion conditions. Due to current smelter technology limitations, the SO_2 ground level concentration control order limit is 0.50 ppm for a 1-hour running average computed from consecutive 5 minute averages.

The years 1988 to 1991 have shown a slight increase in the annual mean SO_2 levels on average *(Figure 46)* and a significant increase in the number of hours and days exceeding the provincial AAQC. These increases are the direct result of the "Copper Cliff" SO_2 monitoring station commissioned in 1988 to measure the impact of roof-level fugitive emissions of SO_2 from the converter aisle at the Inco Ltd. Copper Cliff smelter. The Copper Cliff station is believed to be affected mostly by fugitive emissions with little (if any) contribution from the "tall" stack. Conversely, the monitor at the Science North complex is believed to be mostly affected by elevated SO_2 releases (stack emissions) with little (if any) contribution from fugitive emissions.

Of the 166 hours which exceeded the 1-hour AAQC at the Science North station from 1984 to 1992, the majority occurred between 1200 EST and 1700 EST *(Figure 47)*. The meteorological data obtained from the CKNC tower indicate that moderate winds and/or relatively unstable conditions (as indicated by the temperature lapse rate) prevailed for approximately 70% of these events. In some cases, pollutant concentrations were elevated and short-lived indicating that they were generally associated with plume looping events. The monthly distribution of these 166 exceedance hours appears in *Figure 48*. A definite pattern exists as the frequency of exceedances generally increases into the spring and summer months and decreases again with the on-set of fall and winter. No exceedances were recorded in July as smelter operations shut down for maintenance and vacation purposes.

While long-term trends have shown improvements in Sudbury's ambient SO_2 air quality, the potential for short term fumigations resulting

FIGURE 46

Range of Annual SO_2 Levels at Monitoring Sites in Sudbury, 1971-1992

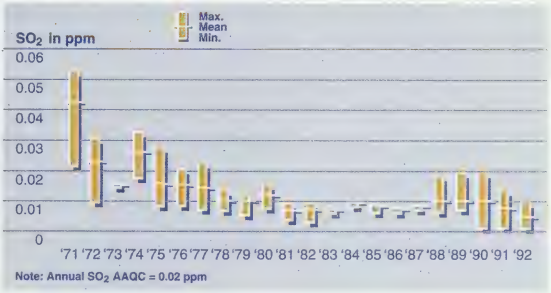


FIGURE 47

Diurnal Distribution of SO_2 Hourly Exceedances at Science North, 1984-1992

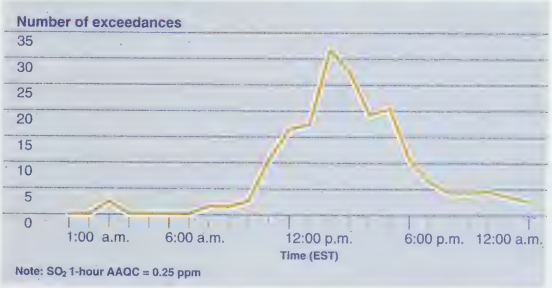
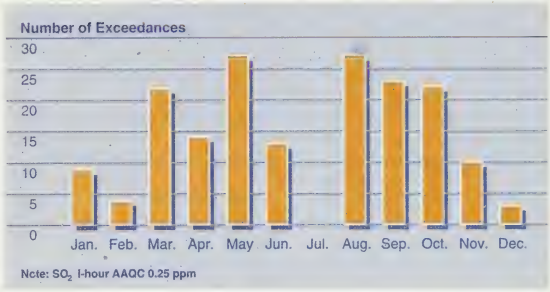


FIGURE 48

Hourly Exceedances at Science North, 1984-1992



in discomfort to people and possible injury to vegetation still exists. The Ontario Ministry of the Environment acknowledges this problem and is working towards ensuring that Inco and Falconbridge continue to operate within the requirements of their control orders and also work towards developing and implementing new control strategies and programs.

In Ontario, there are two historic examples of sulphur dioxide damage (in combination with forest fires, lumbering practices and metal emissions) at Sudbury and Wawa. The legacy of the emissions from the local mining industries is a severe loss of vegetation and a poor public image of the area, especially at Sudbury.

For over twenty years, considerable effort has been made to curtail the emissions from the smelter operations at Sudbury. This effort has greatly reduced the number of occasions during the summer growing season when the combination of gas concentration and duration of a sulphur dioxide fumigation is sufficiently high to exceed specified conditions are termed "Potentially Injurious Fumigations". With the improved air quality in recent years, it has been possible to revegetate much of the industrial barren land in the Sudbury area with grass and trees. Although much remains to be done in the area of emission abatement and in revegetation of the area, the land reclamation project and reduction in sulphur dioxide emissions has demonstrated that a well-organized and concentrated effort can significantly reverse environmental degradation.

26.2 CASE STUDY 2 — Impact of Vehicle Emissions on Air Quality Levels in Toronto

As was mentioned earlier in this report, the transportation sector accounts for 75%, 60% and 20% of Ontario's total emissions of carbon monoxide, nitrogen oxides, and suspended particles, respectively. This translates into approximately 1875 kilo-tonnes of CO, 330 kilo-tonnes of NO_x and 40 kilo-tonnes of SP being emitted into Ontario's air annually. It is therefore, not surprising that during rush hour traffic periods within the major urban centres, concentrations of these vehicle-related pollutants show sharp increases.

Figure 49 shows the daily build up of CO, NO_x and SP at the Bay/Grosvenor monitoring site in downtown Toronto on Earth Day April 22, 1992. All three pollutants behaved similarly and reached peak concentrations during the morning rush hour period, 0700 to 1000 EST. During the majority of afternoon rush hour periods, elevated levels of CO, NO_x and SP are not as pronounced as during the morning rush hour period. This is due to the associated meteorology which plays a significant role in determining the magnitude of these pollutants levels. The morning rush hour periods are characterized by light wind conditions which limit vertical mixing and dispersion, resulting in the build up of pollutants levels. In the afternoon, the winds generally increase in speed which causes more mixing of the pollutants resulting in lower concentrations. This was evident on April 22 as the concentrations during the afternoon rush hour period remained low, compared to the morning period, due to the stronger winds which are conducive to better dispersion.

26.3 CASE STUDY 3 — Lead Levels in the Vicinity of a Secondary Lead Plant in Toronto

Canada Metals Company operates a secondary lead smelter at 721 Eastern Avenue, Toronto. Lead emissions from the plant have been a major concern to the residents of the adjacent South Riverdale community. Ministry Control Orders were issued to the company in 1973, 1976 and 1979 with respect to lead abatement measures.

Lead (Pb) in TSP

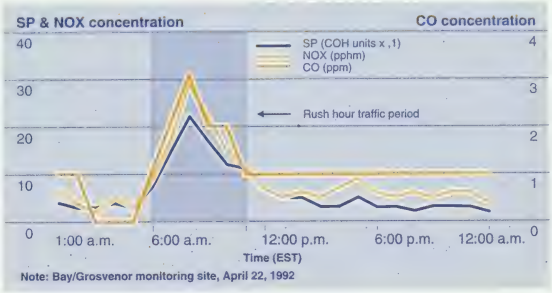
Information on monitoring for lead in total suspended particulate (TSP) is referenced in *Section 16.0* of this report.

The Ministry has monitored for lead in total suspended particulate (TSP) and lead in dustfall in the vicinity of the Canada Metals Company since 1973. *Table 12a* shows the annual geometric mean lead in TSP levels at 5 hi-vol monitoring stations the ministry has operated during this time. At the present four of these stations continue to operate. Two stations (#31058 and #31065) are located in industrial properties adjacent to the smelter, one (#31045) is located on the roof of a school approximately 250 metres to the NNW and one (#31082) is located approximately 1.8 kilometres WNW of Canada Metals. The location of these stations are shown on the map in *Figure 50*. Station #31082 was set-up as a control site to measure general ambient lead levels away from the plant for comparison purposes. Initially there were three control stations, two of which operated for a short period of time and were removed.

Although there is no annual criterion for levels of lead in TSP the results in *Table 12a* and in *Figure 50* do show a decreasing annual trend in annual geometric mean concentration.

FIGURE 49

Daily Variation of Vehicle Related Pollutants in Downtown Toronto



Note: Bay/Grosvenor monitoring site, April 22, 1992

TABLE 12(a)

Annual Geometric Mean Lead in TSP at Sites Near a Secondary Lead Plant in Toronto, 1973 to 1992

Year	MOEE Station 31045	MOEE Station 31058	MOEE Station 31064	MOEE Station 31065	MOEE Station 31082
1973	1.21	5.68			
1974	1.03	2.53	1.23	1.69	1.27
1975		2.10	0.91	1.43	1.14
1976		2.45	1.11	1.32	1.07
1977		2.12	0.98	1.30	1.11
1978		1.72	0.75	1.17	1.11
1979		1.65	0.55	1.19	0.78
1980		1.18	0.44	0.78	0.58
1981		0.76	0.48	0.65	0.66
1982		0.58	0.38		0.36
1983		0.54	0.34		0.38
1984		0.70	0.48		0.44
1985		0.55	0.37		0.33
1986		0.47	0.08		0.33
1987	0.12	0.56			0.14
1988	0.06	0.50		0.23	0.08
1989	0.08	0.36		0.27	0.03
1990	0.07	0.40		0.28	0.01
1991	0.05	0.30		0.21	0.01
1992	0.06	0.17		0.23	0.01

FIGURE 50

Annual Geometric Mean Lead Concentrations in TSP at Sites Near the Canada Metals Company, 1973 to 1992

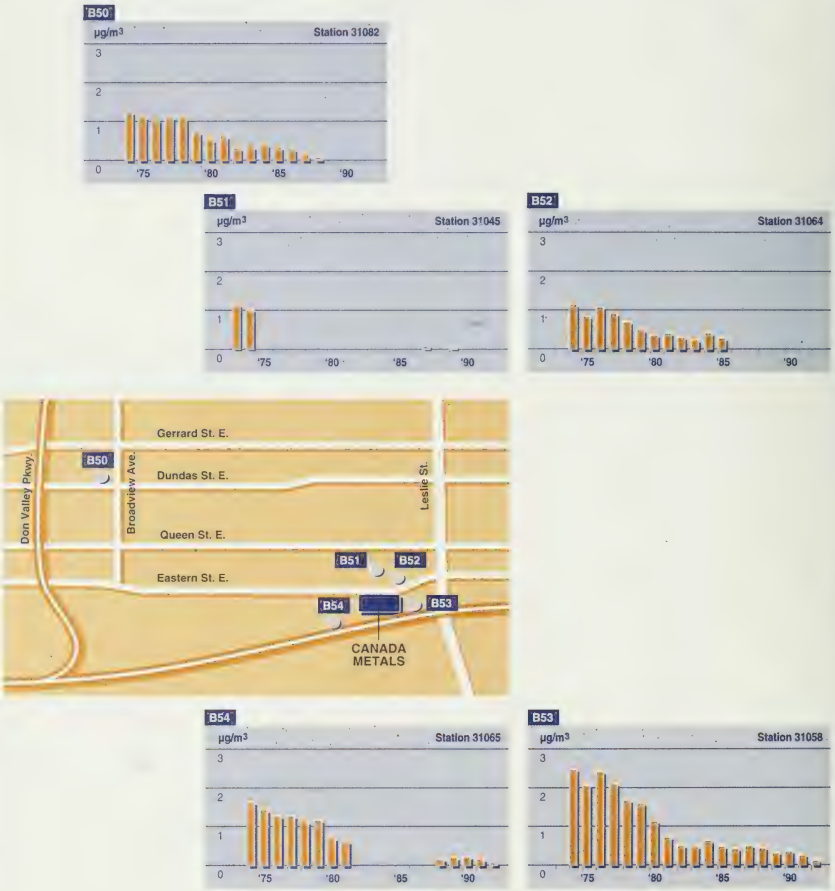


TABLE 12(b)

Number of Exceedances of the 24-Hour AAQC for Lead in TSP at Sites Near a Secondary Lead Plant in Toronto, 1973 to 1992

Year	MOEE Station 31045	MOEE Station 31058	MOEE Station 31064	MOEE Station 31065	MOEE Station 31082
1973	0	38			
1974	0	32	5	41	1
1975		46	5	38	2
1976		71	6	29	1
1977		66	6	39	0
1978		62	5	36	0
1979		76	4	69	1
1980		42	3	15	0
1981		0	0	1	1
1982		3	0		0
1983		0	1		0
1984		3	0		0
1985		6	0		0
1986		9	0		0
1987		13			0
1988	0	3		0	0
1989	0	2		1	0
1990	0	5		7	0
1991	0	4		8	0
1992	0	0		1	0

24-Hour AAQC for Lead in TSP = 5.0 $\mu g/m^3$

Table 12b lists the number of exceedances of the 24-hour lead in TSP AAQC at sites near the Canada Metals Plant since 1973. The total number of exceedances has decreased dramatically over the 20-year period. In 1992 there was only 1 exceedance of the lead in TSP 24-hour AAQC at monitoring sites near the Canada Metals Plant.

Lead in Dustfall

Lead in dustfall was measured at a total of eight dustfall stations since 1972 to the present. Five of these sites were co-located with the hi-vol monitors and three sites measured dustfall only. Three additional control stations for lead in dustfall operated since 1974 and were co-located with the three hi-vol stations mentioned in the previous paragraph. At the present time five of the eight dustfall sites and one control site (#31082) continue to operate.

Figure 51 shows a significant decreasing trend in annual Pb in dustfall levels at all sites. The decreasing trend is more dramatic at the sites closest to the plant i.e., #31058, #31059 and #31065.

Ministry Abatement & Enforcement Action

Although levels of lead in TSP and dustfall near Canada Metals have improved, the 24-hour criterion for lead in TSP continues to be exceeded. Elevated levels of lead in TSP are investigated by the Ministry Abatement and Investigations & Enforcement staff.

Largely as a result of the lead emissions, Canada Metals was required by the Ministry to carry out stack testing of plant emissions in 1989 and 1991. The tests showed compliance with federal and provincial lead regulations.

A Director's Order was issued to the company on November 28, 1990, requiring Canada Metals to retain a qualified independent consultant to audit the smelter's pollution control systems, housekeeping, maintenance and employee training programs. The audit report revealed deficiencies, particularly in the areas of housekeeping and employee training. A subsequent Director's Order was issued to the company in December 1991, requiring the company to implement the recommendations of the audit report. The company is currently in compliance with the Order.

FIGURE 51

Annual Mean Lead Concentrations in Dustfall at Sites Near the Canada Metals Company, 1973 to 1992

TABLE 10(a)

10 - Year Trend for SO_2

City	Annual Mean (ppm)									
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Burlington	0.005	0.005	0.004	0.004	0.004	0.004	0.007	0.006	0.003	0.006
Cornwall	0.008	0.009	0.009	0.008	0.006	0.006	0.007	0.005	0.005	0.005
Etobicoke	0.006	0.007	0.007	0.005	0.005	0.006	0.005	0.006	0.006	0.008
Hamilton	0.014	0.015	0.009	0.008	0.007	0.008	0.010	0.007	0.007	0.007
Kitchener	0.002	0.003	0.002	0.003	0.004	0.003	0.003	N/A	0.003	0.003
London	0.003	0.004	0.002	0.003	0.003	0.004	0.006	0.004	0.005	0.004
Long Point	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.004	0.004	0.005
Mississauga	0.006	0.006	0.006	0.007	0.009	0.004	0.004	0.004	0.005	0.006
Niagara Falls	0.003	0.004	0.003	0.003	0.002	0.005	0.005	0.005	0.005	0.004
North Bay	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.001	N/A
North York	0.006	0.009	0.008	0.005	0.002	0.002	0.002	0.002	0.002	0.003 *
Oakville	0.005	0.007	0.006	0.005	0.003	0.005	0.006	0.005	0.005	0.004
Oshawa	0.003	0.005	0.003	0.003	0.004	0.006	0.006	0.004	0.004	0.004
Ottawa	0.002	0.002	0.002	0.002	0.001	0.002	0.003	0.002	0.003	0.002
Peterborough	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	N/A
Sarnia	0.010	0.009	0.011	0.008	0.007	0.009	0.008	0.012	0.009	0.009
Scarborough	0.003	0.004	0.003	0.003	0.004	0.008	0.006	0.006	0.004	0.003
Simcoe	0.003	0.004	0.005	0.003	0.003	0.005	0.005	0.004	0.003	0.003
St. Catharines	0.005	0.005	0.006	0.005	0.010	0.011	0.006	0.004	0.005	0.005
Stouffville	0.005	0.005	0.004	0.002	0.002	0.003	0.004	0.003	0.004	0.003
Sudbury	0.009	0.010	0.010	0.008	0.009	0.010	0.008	0.008	0.005	0.004
Thunder Bay	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tiverton	0.003	0.007	0.002	0.001	0.001	0.003	0.002	0.001	0.001	0.001
Toronto	0.004	0.006	0.004	0.004	0.004	0.007	0.008	0.006	0.005	0.008
Windsor	0.008	0.007	0.007	0.008	0.008	0.011	0.008	0.007	0.007	0.006
Provincial Mean	0.005	0.006	0.005	0.004	0.004	0.005	0.005	0.005	0.004	0.004

*1992 Site changed location from Science Centre (34002) to North York (34020)

TABLE 10(b)

10-Year Trend for CO

	Annual Mean (ppm)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cornwall	0.2	0.2	0.2	0.2	0.3	0.6	0.8	0.6	0.8	0.5
Etobicoke	1.6	1.4	1.3	1.2	1.2	1.2	0.7	0.8	0.8	0.6
Hamilton	0.9	0.8	1.2	1.1	1.2	1.2	1.2	1.2	1.1	1.2
Kitchener	1.0	0.9	0.8	0.9	0.8	0.9	1.1	N/A	0.6	0.5
London	0.3	0.4	0.3	0.3	0.4	0.5	0.9	0.6	0.7	0.7
Mississauga	1.4	1.4	1.9	1.4	1.3	1.0	1.1	1.1	1.1	1.1
North York	N/A	1.3	1.4	1.3	1.2	0.8	0.8	1.0	0.7	1.0 *
Oakville	1.3	0.9	1.0	1.0	0.8	0.9	0.9	0.5	0.5	0.3
Oshawa	2.0	1.8	1.0	1.2	0.8	1.1	0.9	0.9	0.8	0.9
Ottawa	0.2	0.3	0.6	0.6	0.3	0.5	0.7	0.7	1.0	1.1
Sarnia	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.3
Scarborough	1.2	1.4	1.3	1.0	1.1	1.0	1.2	1.2	1.0	0.8
St. Catharines	0.4	0.4	0.2	0.2	N/A	1.0	0.9	1.0	0.7	0.5
Sudbury	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.5	0.3	0.1
Toronto	1.1	1.0	1.1	1.0	1.1	0.6	0.9	1.1	1.1	1.0
Windsor	0.8	0.5	0.5	0.5	0.7	0.9	1.0	1.2	1.0	0.9
Provincial Mean	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.7

*1992 Site changed location from Science Centre (34002) to North York (34020)

TABLE 10(c)

10-Year Trend for NO_2

	Annual Mean (ppm)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cornwall	0.011	0.011	0.010	0.011	0.010	0.008	0.009	0.008	0.006	0.010
Etobicke	0.021	0.024	0.026	0.027	0.028	0.021	0.030	0.026	0.025	0.026
Hamilton	0.029	0.029	0.025	0.027	0.026	0.024	0.026	0.022	0.022	0.019
Kitchener	0.025	0.027	0.029	0.032	0.026	0.027	0.025	N/A	0.013	0.015
London	0.021	0.024	0.025	0.026	0.021	0.020	0.022	0.021	0.019	0.018
Mississauga	0.026	0.026	0.026	0.026	0.025	0.021	0.025	0.020	0.022	0.023
North York	0.023	0.026	0.027	0.023	0.025	0.027	0.028	0.028	0.029	0.024 *
Oakville	0.016	0.018	0.016	0.020	0.017	0.016	0.016	0.017	0.017	0.016
Oshawa	0.019	0.021	0.020	0.021	0.022	0.024	0.024	0.019	0.018	0.018
Ottawa	0.014	0.014	0.012	0.012	0.015	0.016	0.017	0.016	0.020	0.017
Sarnia	0.020	0.023	0.019	0.021	0.012	0.015	0.019	0.021	0.019	0.020
Scarborough	0.019	0.018	0.018	0.022	0.022	0.025	0.027	0.025	0.024	0.019
Simcoe	0.009	0.009	0.006	0.005	0.005	0.008	0.010	0.005	0.007	0.010
St. Catharines	0.020	0.018	0.017	0.019	N/A	0.018	0.021	0.016	0.016	0.012
Sudbury	0.006	0.006	0.007	0.010	0.011	0.010	0.011	0.009	0.009	0.009
Toronto	0.025	0.027	0.026	0.027	0.025	0.025	0.027	0.025	0.029	0.027
Windsor	0.026	0.027	0.026	0.025	0.027	0.030	0.027	0.025	0.025	0.025
Provincial Mean	0.019	0.020	0.020	0.021	0.020	0.020	0.021	0.019	0.019	0.018

*1992 Site changed location from Science Centre (34002) to North York (34020)

TABLE 10(d)

10-Year Trend for NO

City	Annual Mean (ppm)									
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cornwall	0.008	0.007	0.008	0.005	0.011	0.010	0.009	0.008	0.006	0.008
Etobicoke	0.026	0.026	0.027	0.031	0.028	0.026	0.029	0.023	0.019	0.025
Hamilton	0.018	0.023	0.019	0.022	0.014	0.017	0.014	0.012	0.011	0.015
Kitchener	0.045	0.046	0.047	0.051	0.051	0.047	0.045	N/A	0.005	0.006
London	0.014	0.017	0.013	0.019	0.018	0.015	0.015	0.016	0.011	0.013
Mississauga	0.027	0.028	0.030	0.032	0.030	0.026	0.024	0.019	0.020	0.022
North York	0.030	0.027	0.028	0.022	0.026	0.021	0.026	0.038	0.020	0.021 *
Oakville	0.012	0.017	0.016	0.020	0.018	0.036	0.030	0.015	0.011	0.013
Oshawa	0.013	0.023	0.017	0.016	0.019	0.014	0.018	0.020	0.014	0.014
Ottawa	0.009	0.012	0.011	0.010	0.012	0.011	0.012	0.009	0.009	0.011
Sarnia	0.010	0.008	0.007	0.009	0.006	0.006	0.007	0.007	0.006	0.007
Scarborough	0.028	0.033	0.032	0.032	0.035	0.033	0.033	0.027	0.026	0.025
Simcoe	0.002	0.005	0.004	0.007	0.005	0.002	0.001	0.001	0.002	0.002
St. Catharines	0.009	0.016	0.009	0.008	N/A	0.010	0.011	0.011	0.008	0.014
Sudbury	0.005	0.007	0.010	0.008	0.008	0.005	0.006	0.005	0.005	0.004
Toronto	0.019	0.021	0.019	0.022	0.021	0.018	0.022	0.021	N/A	0.025
Windsor	0.016	0.028	0.015	0.021	0.014	0.014	0.015	0.016	0.019	0.018
Provincial Mean	0.017	0.020	0.018	0.020	0.020	0.018	0.019	0.016	0.012	0.014

*1992 Site changed location from Science Centre (34002) to North York (34020)

TABLE 10(e)

10-Year Trend for NO_x

City	Annual Mean (ppm)									
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cornwall	0.019	0.018	0.018	0.016	0.021	0.017	0.019	0.018	0.016	0.019
Etobicoke	0.046	0.048	0.053	0.059	0.057	0.046	0.061	0.050	0.044	0.051
Hamilton	0.047	0.053	0.044	0.049	0.039	0.041	0.040	0.035	0.033	0.033
Kitchener	0.072	0.074	0.076	0.083	0.075	0.073	0.070	0.039	0.021	0.022
London	0.035	0.042	0.038	0.044	0.038	0.035	0.037	0.034	0.031	0.034
Mississauga	0.054	0.054	0.055	0.059	0.054	0.047	0.048	0.039	0.042	0.042
North York	0.053	0.053	0.055	0.046	0.050	0.049	0.054	0.066	0.049	0.045 *
Oakville	0.028	0.035	0.032	0.040	0.035	0.036	0.042	0.031	0.028	0.030
Oshawa	0.033	0.044	0.038	0.038	0.042	0.036	0.042	0.040	0.032	0.033
Ottawa	0.023	0.026	0.024	0.023	0.028	0.026	0.029	0.025	0.029	0.028
Sarnia	0.029	0.031	0.027	0.030	0.019	0.021	0.028	0.029	0.026	0.026
Scarborough	0.047	0.051	0.050	0.055	0.057	0.058	0.060	0.051	0.050	0.046
Simcoe	0.011	0.013	0.010	0.012	0.010	0.010	0.012	0.007	0.009	0.013
St. Catharines	0.029	0.034	0.026	0.027	N/A	0.029	0.033	0.027	0.024	0.027
Sudbury	0.010	0.009	0.016	0.018	0.019	0.015	0.016	0.014	0.014	0.014
Toronto	0.044	0.048	0.044	0.048	0.047	0.044	0.048	0.046	0.054	0.052
Windsor	0.041	0.055	0.041	0.046	0.041	0.044	0.042	0.041	0.042	0.042
Provincial Mean	0.037	0.040	0.038	0.041	0.040	0.037	0.040	0.035	0.032	0.033

*1992 Site changed location from Science Centre (34002) to North York (34020)

TABLE 10(f)

10-Year Trend for O_3 (ppb)

	Annual Mean (ppb)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cornwall	22.7	27.6	25.8	22.8	20.8	24.0	20.4	21.2	20.7	20.8
Etobicoke	15.7	16.5	18.1	16.7	16.0	19.3	16.9	16.4	19.0	15.4
Hamilton	18.7	18.0	19.0	16.4	16.2	17.9	16.7	17.6	19.9	16.9
Huron Park	24.2	26.5	26.5	26.1	25.9	29.7	28.0	27.4	N/A	29.7
Kitchener	18.9	18.3	19.9	17.0	17.1	21.6	19.9	N/A	27.2	22.7
London	21.0	19.4	21.3	18.4	19.4	23.7	22.9	22.1	22.7	20.3
Long Point	29.9	31.2	34.4	31.4	31.7	38.4	35.7	33.0	33.9	32.3
Mandaumin	19.1	25.9	27.9	23.1	25.9	30.0	28.4	23.7	28.1	23.5
Merlin	22.6	21.0	22.0	19.8	27.3	31.5	27.2	26.0	28.4	24.3
Mississauga	16.6	15.4	16.0	15.7	14.5	17.7	18.6	17.8	18.6	15.6
North York	18.3	15.5	11.8	7.4	8.9	9.0	12.8	13.3	14.7	16.3 **
Oakville	18.1	16.7	19.6	18.5	19.8	20.9	22.1	22.2	22.1	19.3
Oshawa	21.1	17.1	18.2	17.2	17.9	20.2	21.9	18.8	22.6	20.3
Ottawa	17.6	17.8	19.2	17.3	16.1	20.7	20.9	21.5	20.8	17.4
Sarnia	23.0	23.3	22.9	20.9	21.8	22.6	25.3	21.4	23.4	21.3
Scarborough	16.7	14.9	13.9	16.6	16.8	17.7	17.9	17.6	19.1	14.3
Simcoe	30.0	28.7	30.6	27.6	28.4	31.2	28.6	26.3	29.1	25.1
St. Catharines	23.2	20.3	17.9	21.9	N/A	23.6	20.8	23.8	25.0	19.3
Stouffville	20.5	21.0	23.3	20.0	22.9	26.6	28.1	24.9	25.0	23.0
Sudbury	14.2	15.8	13.4	17.1	19.4	29.5 *	28.9	27.2	27.0	25.4
Tiverton	27.3	27.3	34.6	27.5	33.0	34.6	33.1	31.3	34.2	33.4
Toronto	14.3	16.7	17.1	16.2	15.4	17.5	16.9	15.7	18.0	12.5
Windsor	18.7	18.9	19.7	17.4	17.6	23.5	20.6	17.1	17.6	15.1
ProvincialL Mean	20.5	20.6	21.4	19.7	20.6	24.0	23.2	22.1	23.5	21.1

* Site changed from downtown Ash Street to Sudbury Science Centre North
**Site changed location from Science Centre (34002) to North York (34020)

TABLE 10(g)

10-Year Trend for SP

	Annual Mean (ppb)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cornwall	0.18	0.16	0.09	0.06	0.04	0.10	0.11	0.19	0.17	0.19
Etobicoke	0.37	0.52	0.47	0.54	0.52	0.43	0.32	0.44	0.32	0.32
Hamilton	0.44	0.55	0.52	0.57	0.55	0.46	0.50	0.42	0.41	0.45
London	0.31	0.29	0.30	0.30	0.27	0.25	0.33	0.28	0.25	0.24
Niagara Falls	0.20	0.22	0.20	0.18	0.20	0.32	0.25	0.24	0.20	0.21
North York	0.57	0.62	0.56	N/A	N/A	0.34	0.41	0.30	0.33	0.31*
Oshawa	0.33	0.40	0.37	0.33	0.37	0.31	0.37	0.37	0.35	0.31
Ottawa	0.18	0.19	0.14	0.15	0.19	0.23	0.36	0.35	0.25	0.28
Sarnia	0.27	0.29	0.25	0.31	0.29	0.24	0.30	0.28	0.24	0.22
Scarborough	0.32	0.36	0.34	0.34	0.38	0.37	0.42	0.36	0.34	0.30
Sudbury	0.12	0.15	0.13	0.16	0.16	0.21	0.18	0.12	0.17	0.17
St. Catharines	0.27	0.24	0.26	0.24	0.27	0.23	0.25	0.25	0.25	0.26
Toronto	0.41	0.47	0.36	0.39	0.38	0.34	0.37	0.38	0.40	0.39
Windsor	0.47	0.46	0.41	0.43	0.37	0.44	0.40	0.40	0.30	0.34
Provincial Mean	0.32	0.35	0.31	0.31	0.31	0.31	0.33	0.31	0.28	0.29

* Site changed location from Science Centre (34002) to North York (34020)

TABLE 10(h)
10-Year Trend for TRS

	Annual Mean (ppb)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cornwall	3.4	1.5	0.8	2.6	4.3	2.5	3.4	3.4	2.9	2.3
Fort Frances	4.9	2.8	2.0	3.9	5.5	5.9	4.9	5.5	4.3	4.2
Hamilton	1.4	1.8	1.4	1.4	0.9	0.8	0.8	0.9	0.8	0.6
Oakville	1.2	2.8	2.4	2.4	1.6	1.4	1.1	1.3	1.6	0.5
Tiverton	0.1	0.1	0.1	0.1	0.4	0.9	0.4	0.0	0.0	0.1
Thunder Bay	0.5	0.6	0.8	1.0	0.8	1.0	1.0	0.2	0.2	0.3
Provincial Mean	1.9	1.6	1.3	1.9	2.3	2.1	1.9	1.9	1.6	1.3

TABLE 10(i)
10-Year Trend for TSP

	Annual Geometric Mean ($\mu g/m^3$)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Bramalea	65	66	62	59	63	60	75	N/A	39	41
Burlington	49	57	53	45	50	42	56	39	42	34
Courtright	33	37	34	36	34	34	36	30	26	28
Espanola	46	45	42	37	40	37	50	44	45	38
Etobicoke	44	46	51	63	51	43	48	35	46	36
Fort Frances	33	32	26	29	29	26	29	28	25	20
Hamilton	75	81	71	76	77	68	75	64	61	59 **
Jarvis	46	49	49	44	43	43	52	34	41	30
London	52	55	42	50	65	54	57	52	52	43
Mississauga	60	68	55	53	56	54	58	48	44	40
North York	38	39	40	40	40	47	41	44	42	41 *
Oakville	40	47	43	43	45	44	56	48	45	37
Orillia	42	43	42	40	41	64	47	N/A	N/A	37
Oshawa	42	44	41	43	51	48	58	47	46	37
Pickering	41	47	49	47	44	52	53	N/A	58	56
Port Colborne	51	57	49	54	45	46	51	50	47	41
S.S.Marie	35	37	36	34	35	35	33	35	32	27
Sarnia	59	45	46	45	42	42	37	34	34	31
Scarborough	51	60	53	55	53	51	67	48	54	48
St. Catharines	68	58	50	60	47	46	55	45	43	40
St. Thomas	57	59	56	51	65	54	45	38	34	32
Sudbury	40	34	31	32	35	30	41	42	34	29
Thunder Bay	35	44	36	40	35	37	36	32	33	30
Toronto	54	54	50	51	52	58	60	60	51	43
Welland	49	58	48	42	48	51	48	48	49	35
Windsor	53	57	59	63	68	62	61	60	51	41
Provincial Mean	47	50	46	46	47	46	50	44	43	37

* 1992 site changed location from Science Centre (34002) to North York (34020)
** 1988 site changed location from Barton/Sanford (29025) to Elgin/Kelly St. (29000)

TABLE 10(j)

10-Year Trend for Pb in TSP

	Annual Geometric mean (µg/m³)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Bramalea	0.30	0.20	0.20	0.20	0.10	0.04	0.03	N/A	0.02	0.01
Etobicoke	0.30	0.20	0.20	0.20	0.10	0.03	0.01	0.01	0.01	0.01
Hamilton	0.40	0.40	0.30	0.30	0.20	0.12	0.09	0.03	0.02	0.03
London	0.30	0.30	0.20	0.10	0.10	0.07	0.04	0.01	0.01	0.01
Mississauga	0.30	0.30	0.20	0.20	0.10	0.03	0.01	0.01	0.01	0.01
North York	0.30	0.30	0.20	0.20	0.10	N/A	0.01	0.01	0.01	0.01*
Oshawa	0.20	0.20	0.20	0.10	0.10	0.03	0.01	0.01	0.02	0.00
S.S. Marie	0.20	0.20	0.20	0.10	0.10	0.03	0.03	0.01	0.01	0.00
Sarnia	0.20	0.10	0.10	0.10	0.00	0.03	0.01	0.01	0.01	0.01
Scarborough	0.30	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.01	0.01
Sudbury	0.10	0.10	0.10	0.10	0.10	0.05	0.03	0.01	0.01	0.01
Thunder Bay	0.20	0.20	0.10	0.10	0.10	0.05	0.03	0.01	0.01	0.00
Toronto	0.30	0.30	0.20	0.20	0.10	0.07	0.04	0.02	0.02	0.02
Windsor	0.20	0.20	0.20	0.20	0.10	0.06	0.03	0.02	0.02	0.02
Provincial Mean	0.26	0.24	0.19	0.16	0.10	0.05	0.03	0.01	0.01	0.01

- beginning in 1988 lead reported to two significant digits.
* 1992 site changed location from Science Centre (34002) to North York (34020)

TABLE 10(k)

10-Year Trend for Mn in TSP

	Annual geometric mean (µg/m³)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Hamilton	0.128	0.152	0.187	0.175	0.157	0.188	0.199	0.198	0.156	0.170
London	0.026	0.024	0.022	0.018	0.033	0.028	0.033	0.027	0.023	0.020
Sarnia	0.022	0.010	0.023	0.014	0.018	0.024	0.011	0.009	0.009	0.009
S.S.Marie	0.032	0.029	0.068	0.040	0.058	0.058	0.062	0.062	0.037	0.031
Sudbury	0.005	0.007	0.016	0.009	0.019	0.017	0.021	0.020	0.014	0.012
Thunder Bay	0.021	0.025	0.043	0.033	0.027	0.021	0.042	0.032	0.029	N/A
Toronto	0.021	0.026	0.032	0.024	0.041	0.040	0.042	0.044	0.040	0.032
Windsor	0.034	0.041	0.055	0.047	0.064	0.057	0.048	0.044	0.030	0.024
Provincial Mean	0.031	0.034	0.048	0.038	0.046	0.047	0.050	0.055	0.042	0.043

TABLE 10(l)

10-Year Trend for Cu in TSP

	Annual geometric mean (µg/m³)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Hamilton	0.32	0.30	0.23	0.15	0.15	0.08	0.09	0.06	0.11	0.11
London	0.33	0.21	0.16	0.13	0.28	0.07	0.03	0.03	0.02	0.02
S.S.Marie	0.26	0.14	0.16	0.14	0.12	0.06	0.09	0.07	0.14	0.10
Sudbury	0.22	0.27	0.15	0.24	0.17	0.10	0.18	0.14	0.15	0.09
Thunder Bay	0.18	0.19	0.19	0.07	0.06	0.04	0.05	0.03	0.03	N/A
Toronto	0.16	0.15	0.12	0.11	0.12	0.10	0.08	0.09	0.08	0.08
Windsor	0.16	0.09	0.09	0.10	0.13	0.05	0.03	0.04	0.02	0.01
Provincial Mean	0.23	0.19	0.16	0.13	0.15	0.07	0.08	0.07	0.08	0.07

TABLE 10(m)

10-Year Trend for Fe in TSP

	Annual geometric mean (µg/m³)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Hamilton	2.2	2.3	1.9	2.6	2.5	2.7	2.4	2.2	1.9	1.9
London	0.6	0.6	0.5	0.5	0.8	0.7	0.6	0.5	0.5	0.4
Sarnia	0.5	0.4	0.5	0.4	0.4	0.5	0.3	0.3	0.3	0.2
S.S.Marie	0.5	0.7	1.2	0.6	1.1	0.9	1.1	0.9	0.8	0.5
Sudbury	0.9	0.8	0.7	0.6	0.8	0.8	0.7	0.8	0.7	0.4
Thunder Bay	0.9	1.2	0.8	1.0	N/A	1.0	1.0	0.8	0.7	N/A
Toronto	0.8	0.8	0.7	0.6	0.8	0.9	0.7	0.9	0.8	0.6
Windsor	1.2	1.5	1.5	1.9	2.1	1.9	1.4	1.1	0.9	0.6
Provincial Mean	1.0	1.0	1.0	1.0	1.2	1.2	1.0	0.9	0.8	0.7

TABLE 10(n)
10-Year Trend for NO_3^- in TSP

	Annual geometric mean (µg/m³)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Etobicoke	3.3	3.7	3.0	3.8	2.8	3.1	3.6	N/A	N/A	4.0
Hamilton	3.7	3.8	3.5	3.8	3.9	3.7	4.7	3.3	4.5	3.6
London	3.3	3.6	3.3	3.6	3.9	2.3	3.9	N/A	N/A	3.4
S.S.Marie	1.3	1.2	1.0	0.9	0.9	1.4	1.2	0.8	1.5	1.2
Sudbury	1.5	1.0	0.8	0.6	1.3	0.8	1.2	1.2	1.3	1.1
Thunder Bay	0.7	0.9	0.8	0.9	1.0	1.1	1.3	1.1	1.5	1.1
Toronto	3.6	3.5	3.5	3.4	3.3	3.1	4.2	N/A	3.4	3.3
Windsor	3.4	3.7	3.9	4.3	5.2	4.0	5.1	5.5	4.1	4.4
Provincial Mean	2.8	3.0	2.6	2.6	2.8	2.4	3.1	2.4	2.7	2.8

TABLE 10(o)
10-Year Trend for SO_4^{2-} in TSP

	Annual geometric mean (µg/m³)									
City	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Etobicoke	8.8	9.3	7.7	8.7	8.2	8.4	8.3	N/A	10.2	8.6
Hamilton	10.1	10.9	8.8	11.5	13.0	10.9	11.7	11.0	11.2	11.4
London	7.3	8.7	6.9	7.5	9.4	5.9	8.0	N/A	N/A	7.0
S.S. Marie	7.0	6.8	7.2	5.1	6.4	8.0	4.6	3.7	6.4	6.1
Sudbury	9.1	8.0	6.4	5.6	7.7	5.3	7.0	7.2	6.7	6.7
Thunder Bay	4.0	4.3	3.5	3.6	2.9	3.2	4.7	4.1	5.1	4.4
Toronto	8.7	8.0	7.3	8.0	9.5	7.2	8.3	N/A	7.8	7.1
Windsor	8.3	7.8	9.3	10.4	12.7	9.5	9.5	10.7	9.9	8.7
Provincial Mean	7.9	8.2	7.0	7.3	8.6	7.2	7.7	7.3	8.2	7.5

SECTION H
Meteorology and Air Quality

Weather conditions are a major influence on the air quality levels that are monitored. The weather factors which affect air pollutant concentrations are as follows:

- wind, which transports and disperses pollutants emitted from sources;
- temperature, which affects the amount of fuel used and the dispersion and chemical reactions of pollutants in the atmosphere;
- stability of the atmosphere (ie; stagnant air will allow pollutant concentrations to build up in the atmosphere);
- rainfall, which may remove (washout) pollutants from the atmosphere;
- sunshine, which causes photochemical reactions of air pollutants and leads to the formation of smog.

27.0 Summary of Meteorological Conditions (1992)

The annual mean temperature during 1992 at the majority of weather stations across Ontario was below normal, as the average daytime maximum temperatures during the spring and summer months ranged from 2.0-4.0°C below normal values. During July, which on the average is the hottest month of the year, mean maximum temperatures were 3.0°C below normal at Windsor, 3.7°C at Ottawa, 4.2°C at Sudbury and 4.0°C at Toronto and Thunder Bay. Along with the lower than normal temperatures most weather stations in southern Ontario, during July, recorded more than twice the normal amount of precipitation. For example, Windsor and Ottawa recorded 100 mm of rainfall more than the respective normal amounts of 83 and 85 mm. With the increase in precipitation there was the simultaneous reduction in bright sunshine hours with most stations recording less than 85% of their normal amounts during the summer. During July, Windsor recorded less than 70% of the normal bright sunshine hours (191 hours to the normal 277 hours), Ottawa received 216 hours which is approximately 79% of the normal amount. Toronto received 65% of its normal amount of 189 hours; both Sudbury and Thunder Bay received 66% of their July normal bright sunshine hours (198) in July.

Table 13 shows the number of "hot days" (days with maximum temperatures greater than 30°C) recorded at a number of sites across the province for the years 1988-1992. In this table it can be seen that across the province, the number of "hot days" recorded during 1992 was the least during the period. Windsor recorded only 2 such days compared to greater than 50 days in 1988 and this trend is similar at all sites. In fact none of the sites recorded a "hot day" during July of 1992.

Annual wind roses are presented in *Figure 52* for selected meteorological sites across the province.

TABLE 13

Number of Days Maximum Air Temperature ≥ 30°C, 1988-1992

Station Names	1988	1989	1990	1991	1992
Windsor	52	18	13	41	2
Sudbury	21	10	0	14	0
North Bay	94	3	3	0	0
Ottawa	23	17	15	22	6
Kingston	12	2	2	6	0
Toronto	38	12	9	21	2
Peterborough	31	10	2	19	1
Thunder Bay	15	8	3	11	2
Kitchener	29	10	2	11	1
London	30	7	1	16	0

28.0 Ozone in Ontario

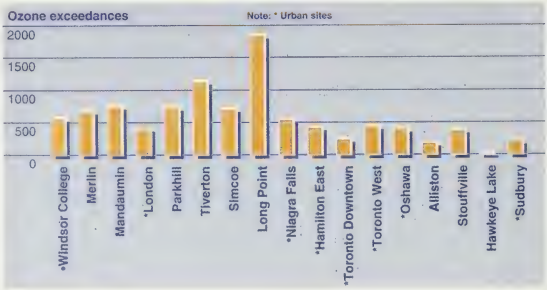
In Ontario, ozone concentrations tend to be highest on hot sunny days for the following reasons: the chemical reactions that produce high concentrations of ozone depend on temperature and bright sunshine; (2) emissions of nitrogen oxides and volatile organic compounds from some sources increase with higher temperatures; and (3) high temperatures are associated with slow moving high pressure systems which allow pollutant concentrations to buildup over a number of days. *Figure 53* shows the meteorological situation which often

FIGURE 52

Annual Wind Roses for Selected Meteorological Sites Across Ontario, 1992

FIGURE 54

Total Number of Ozone Exceedances at Selected Sites in Southern Ontario, 1985-1992



prevails when high levels of ozone are recorded across southern Ontario. Note that the position of the high pressure centre is south of the lower Great Lakes which allows air to be pumped into Ontario from the industrial states bordering Ontario. As a result of this southerly flow, ozone that is produced in the U.S. is transported into Ontario. Note also the distribution in the concentrations of ozone west and east of the cold front. The position of the high pressure system relative to southern Ontario and thus the history of the air parcels, especially those passing over the large pollution sources of the Ohio Valley, lead to high levels of ozone. Within a high pressure system, the air is usually stagnant or

moving slowly, and sunny conditions prevail. As discussed earlier these are two of the conditions favourable for the formation of ozone.

In *Figure 54* the total number of exceedances from 1985 to 1992 at some of Ontario's rural and urban sites are displayed. The number of exceedances at rural sites in southern Ontario are far greater than those at urban sites or at Hawkeye Lake which is situated in northwestern Ontario, north of Thunder Bay. This indicates that the problem is regional with local emissions playing a secondary role.

A large contribution of approximately 50% to 60% to the ground level ozone concentrations in Ontario can be attributed to long range transport of ozone and its precursors from the industrial states south of the lower Great Lakes. *Figure 55* shows the number of ozone exceedances recorded at monitoring sites across southern Ontario during 1992. Long Point and Tiverton on the shores of Lake Erie and Lake Huron respectively recorded the highest number of ozone exceedances. The larger number of exceedances at Long Point and Tiverton, is due in part to lower deposition of ozone over water surfaces as compared to land surfaces and limited mixing of pollutants over the water surface. These ozone data also show the influence of the industrial states on the ozone problem in Ontario.

Generally the higher number of exceedances at rural sites are due to less scavenging of ozone in rural areas and an increase in photochemical production of ozone in the air mass downwind of urban centers. *Figure 56* shows the area from which the air arrives into southern Ontario during days when there are wide-spread elevated levels of O_3 over southern Ontario, for the summers of 1983 to 1992. The figure shows that whenever high

FIGURE 53

Meteorological Pattern Most Favourable for Widespread Ozone Exceedances in Southern Ontario

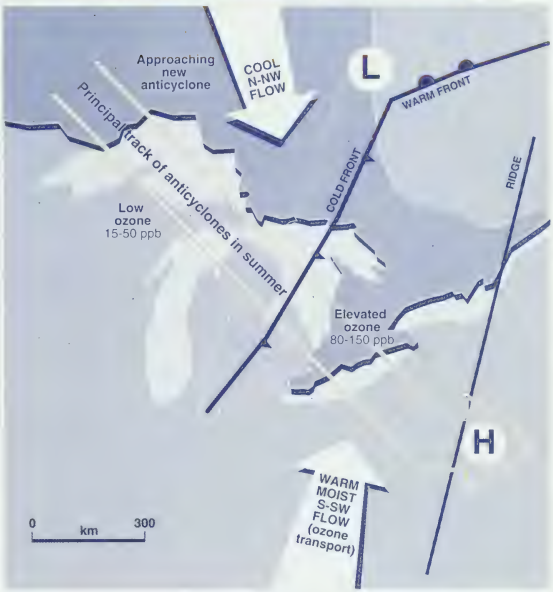


FIGURE 55

OZONE

Number of 1-Hour Exceedances, 1992

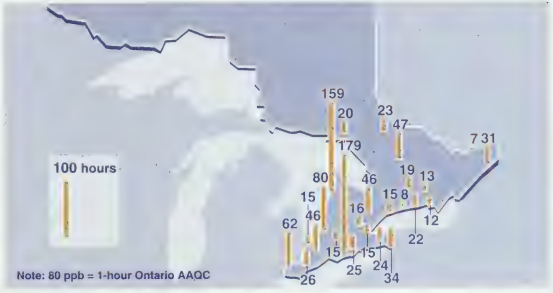


FIGURE 56
Sectorial Area Over Which Air Parcels Resided Prior to Ozone Episodes

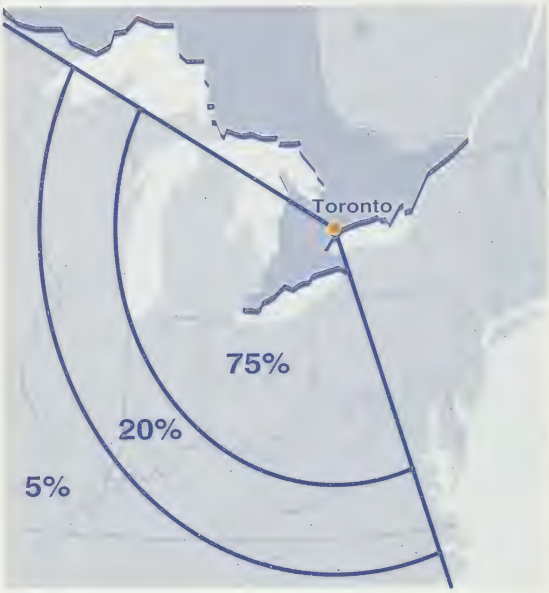
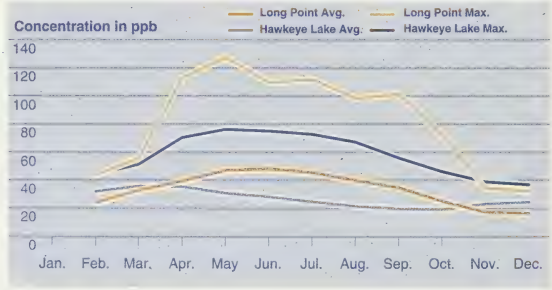


FIGURE 57
Monthly Distribution of Ozone Levels at Long Point and Hawkeye Lake, 1991



ozone days were recorded, the air mass had previously resided over the high emission areas of the states south or west of Ontario and that 75% of the time the air parcels were within a sector of radius 700 km.

Northern vs Southern Ontario

A comparison was made between ozone concentrations at Hawkeye Lake (northern Ontario) which is far removed from high emission areas and Long Point (southern Ontario) which is influenced significantly by ozone transported from the southwest. The analysis is done for 1991 a year in which ozone monitoring sites recorded a large number of exceedances of the ozone 1-hour AAQC of 80 ppb.

The annual average ozone concentrations at Hawkeye Lake and Long Point during 1991 were 29.1 and 33.9 ppb respectively. The monthly average hourly concentrations for these sites are shown in *Figure 57*. During February, 1991 the average ozone concentration was 32 ppb at Hawkeye Lake which was 8 ppb higher than at Long Point. However during June 1991 Long Point recorded a monthly average concentration of 50.3 ppb and this was 20 ppb higher than the corresponding concentration at Hawkeye Lake. The higher monthly average concentration recorded during February at Hawkeye Lake may be, in part, due to stratospheric ozone, since at this time of the year there is a potential for stratospheric ozone to be injected into the troposphere. The northern sites are also far removed from nitrogen oxide emission areas and thus there is less scavenging of ozone than in urban areas. During summer when the conditions are more conducive to photochemical reactions which produce ozone, Long Point which is on the northern

shore of Lake Erie receives the major part of its ozone from the U.S.. Increased ozone production along with limited deposition of ozone to lake surfaces account for the large monthly average seen at Long Point in June 1991.

Although southern Ontario receives a large percentage of its ozone from the U.S during the summer and ozone monitoring sites record more exceedances of the 1-hour ozone AAQC of 80 ppb, the annual concentration at cities in northern Ontario, are higher than at urban sites in southern Ontario. *Figure 58* shows a comparison of the annual average concentrations and the number of ozone exceedances from 1988 to 1992 at Sudbury and Windsor University. Throughout the period the annual average concentration at Sudbury is higher than that at Windsor. However, the number of exceedances at Windsor University is higher than those recorded at Sudbury. The average monthly concentrations at Windsor University and Sudbury for the same period are shown in *Figure 59*. Note that it is only during the month of July that the average monthly concentration of ozone at Windsor University is greater than the monthly average concentration at Sudbury. The monthly averages at Sudbury varied from 18.4 ppb in October to 37.3 ppb in May whereas at Windsor University the monthly averages varied from 7.2 ppb in January to 32.7 ppb in July.

FIGURE 58

Average Annual Ozone Concentrations and Number of 1-Hour Exceedances at Windsor University and Sudbury, 1988-1992

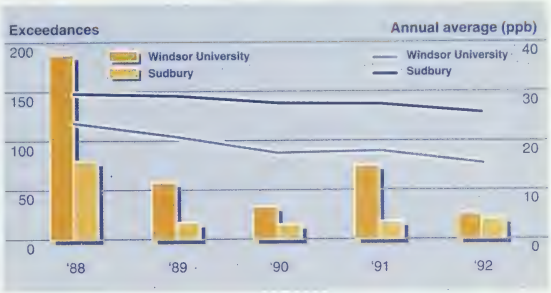
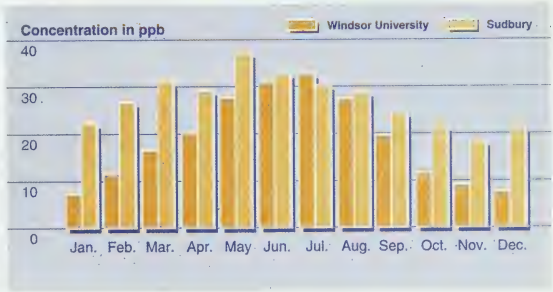


FIGURE 59

Monthly Distribution of Average Ozone Levels at Windsor University and Sudbury, 1988-1992



Occupational Health and Safety

Ozone was recognized as a powerful lung irritant soon after its initial synthesis in 1851. It was placed on the American Conference of Government Industrial Hygienists (ACGIH) threshold limit values (TLVs) for occupational exposure in 1954, with an 8-hour time weighted concentration limit of 100 ppb, and a short term exposure limit of 300 ppb. These limits were based on the provision of protection of the worker from the acute irritant effects of ozone, possible longer term respiratory effects and premature aging, particularly of the elastic tissues of the respiratory tissues. In 1989 the ACGIH revised the exposure limits for ozone by removing the time weighted average limit and introducing a ceiling limit of 100 ppb. The rationale behind this at the time was that ozone caused acute effects but not cumulative effects and the revised limit provided workers, including asthmatics, with protection against these effects. Since 1989 however several studies have reported cumulative effects on the repiratory system following several hours of exposure and the question of reintroducing a longer term limit is likely to re-emerge.

In Ontario, the time weighted average exposure value (TWAEV) is 100 ppb with a 15 minute short term exposure value (STEV) of 300 ppb.

Tables 14 and 15 show for the

TABLE 14

Number of Days With Ozone 8-Hour Running Means > 100ppb at Ozone Sites Across Ontario, 1988-1992

Station	Name	1988	1989	1990	1991	1992
10001	Huron Park	5	0	1	0	N/A
12008	Windsor University	6	1	0	0	0
12016	Windsor College	9	1	0	3	1
13021	Merlin	15	0	0	2	0
14064	Sarnia	2	1	1	1	0
14118	Mandaumin	5	2	1	2	0
15001	London	5	0	1	0	0
15009	Longwoods	1	4	0	2	0
15013	Parkhill	4	0	0	5	0
15020	Grand Bend	N/A	N/A	N/A	N/A	3
18007	Tiverton	13	1	2	6	4
22071	Simcoe	17	0	0	0	0
22901	Long Point	31	10	5	6	0
26060	Kitchener	4	0	0	0	0
26045	Waterloo	0	0	0	1	0
27056	Niagara Falls	8	0	0	0	0
27067	St. Catharines	2	0	0	0	0
28028	Guelph	2	0	0	0	0
29000	Hamilton-Downtown	4	1	0	0	0
29105	Hamilton-East	3	0	0	2	0
29114	Hamilton-Mountain	2	0	1	0	0
29118	Hamilton-West	6	0	2	0	0
31103	Toronto-Downtown	1	0	1	0	0
31120	Toronto-West	4	2	0	1	1
31190	Toronto - CN Tower	14	7	0	6	1
32010	East York	0	0	0	0	0
33003	Scarborough	2	1	0	0	0
34020	North York Central	4	0	0	1	0
34025	North York West	4	0	0	0	0
35003	Etobicoke-West	5	1	0	0	0
35033	Etobicoke-South	1	0	0	0	0
36030	York	6	0	0	1	0
44008	Burlington	1	4	0	1	0
44015	Oakville	6	2	0	0	0
45025	Oshawa	4	3	1	1	0
46110	Mississauga	2	4	0	0	0
47035	Alliston	3	0	0	0	0
48002	Stouffville	4	3	0	0	0
51001	Ottawa	3	0	0	0	0
52020	Kingston	5	1	0	1	N/A
56051	Cornwall	3	0	1	0	0
59006	Peterborough	2	0	0	0	N/A
63100	Hawkeye Lake	0	0	0	0	0
63200	Thunder Bay	0	0	0	0	0
71068	Sault Ste Marie	0	0	0	0	0
75010	North Bay	1	0	0	0	0
77203	Sudbury	0	0	0	0	0

Note: Station 31104 was changed to 31103 in October 1990

TABLE 15

Number of Hours With Ozone 8-Hour Running Means > 100ppb at Ozone Sites Across Ontario, 1988-1992

Station	Name	1988	1989	1990	1991	1992
10001	Huron Park	23	0	2	0	N/A
12008	Windsor University	34	3	0	0	6
12016	Windsor College	43	1	0	6	0
13021	Merlin	63	0	0	7	0
14064	Sarnia	5	9	0	1	0
14118	Mandaumin	20	3	2	8	0
15001	London	15	0	1	0	0
15009	Longwoods	5	20	0	11	0
15013	Parkhill	20	0	0	19	0
15020	Grand Bend	N/A	N/A	N/A	N/A	10
18007	Tiverton	64	5	9	36	28
22071	Simcoe	91	0	0	0	0
22901	Long Point	271	60	17	21	23
26060	Kitchener	12	0	0	0	0
26045	Waterloo	0	0	0	1	0
27056	Niagara Falls	41	0	0	0	0
27067	St. Catharines	9	0	0	0	0
28028	Guelph	8	0	0	0	0
29000	Hamilton-Downtown	14	5	0	0	0
29105	Hamilton-East	9	0	3	11	0
29114	Hamilton-Mountain	11	0	9	0	0
29118	Hamilton-West	27	0	4	0	0
31103	Toronto-Downtown	7	0	0	0	0
31120	Toronto-West	14	4	0	4	1
31190	Toronto - CN Tower	147	36	0	37	9
32010	East York	0	0	0	0	0
33003	Scarborough	8	6	0	0	0
34020	North York Central	22	0	0	5	0
34025	North York West	8	0	0	0	0
35003	Etobicoke-West	13	4	0	0	0
35033	Etobicoke-South	3	0	0	0	0
36030	York	22	0	0	4	0
44008	Burlington	5	13	0	4	0
44015	Oakville	25	7	5	0	0
45025	Oshawa	12	9	0	2	0
46110	Mississauga	10	16	0	0	0
47035	Alliston	11	0	0	0	0
48002	Stouffville	17	14	0	5	0
51001	Ottawa	17	0	0	0	0
52020	Kingston	25	3	5	5	N/A
56051	Cornwall	14	0	0	0	N/A
59006	Peterborough	5	0	0	0	0
63100	Hawkeye Lake	0	0	0	0	0
63200	Thunder Bay	0	0	0	0	0
71068	Sault Ste Marie	0	0	0	0	0
75010	North Bay	2	0	0	0	0
77203	Sudbury	0	0	0	0	0

Note: Station 31104 was changed to 31103 in October 1990

period 1988 to 1992, the number of days and hours respectively when the 8-hour running average of ground level ozone concentration, at the various monitoring sites across Ontario, was greater than or equal to 100 ppb.

Most exceedances occurred at rural sites, particularly at sites nearest the industrial States south of the Lower Great Lakes (e.g. Long Point and Tiverton). There were more exceedances of the 8-hour criterion at rural sites because of less scavenging of ozone in rural areas compared to urban areas; less deposition of ozone over lake surfaces compared to land surfaces and an increase in the photochemical production of ozone in the air mass downwind of urban centres. During the hot dry summer of 1988 only six of the ozone monitoring sites did not exceed the 8-hour 100 ppb criterion on at least one day. Four of these sites are located in northern Ontario. However, during 1992 only six sites exceeded the 8-hour running average of 100 ppb.

Figure 60 shows the average frequency of the hours that the 8-hour running average was exceeded and the hours when the 8-hour average reached 100 ppb (i.e. hour 18 is the time when the average of the 8 preceeding previous hours reached 100 ppb) during the period 1988-1992.

The majority of the exceedances occurred between 1600 and 2000 EST, thus outdoor workers will not be affected unless they continue to work after 1600 EST (1700 EDT). *Table 16* shows some statistics for sites that exceeded the 8-hour, 100 ppb limit during 1992. Long Point recorded the highest maximum 8-hour average concentration of 127 ppb on June 14. In the Greater Metropolitan Toronto Area, the Toronto West site was the only site that recorded an 8-hour running average greater than 99 ppb.

FIGURE 60

Frequency of the Initial Starting Time of Exceedances of the Ozone 8-Hour Running Mean ≥ 100 ppb, 1988 to 1992

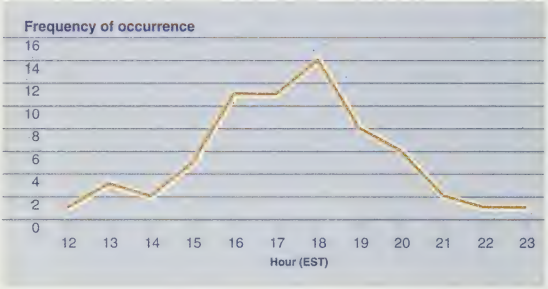


TABLE 16

Summary Statistics for Ozone 8-Hour Running Mean ≥ 100 ppb at Ozone Sites Across Ontario, 1992

Station	Name	Maximum No. of Days	Duration (Hours)*	Date of Max	Maximum 8-Hour Average Concentration (ppb)
12016	Windsor College	1	6	13/6	117
15020	Grand Bend	3	5	22/5	106
18007	Tiverton	4	11	27/6	119
22901	Long Point	4	12	14/6	127
31120	Toronto-West	1	1	22/5	100
31190	Toronto - CN Tower	1	9	22/5	117

*Maximum number of hours that the 8-hour running average was greater than or equal to 100 ppb

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Queries relating to the technical information contained in this report, requests for data or copies of the Appendix should be addressed to:

Ontario Ministry of Environment and Energy
Environmental Monitoring and Reporting Branch
125 Resources Road
Etobicoke, Ontario
M9P 3V6

Telephone (416) 235-6300